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CONTENTS

BULLETIN

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Articles for September *Bulletin*

Regional Stratigraphy of Mid-Continent
By Robert H. Dott

Exercise on Amount of Source Bed Required to Furnish Oklahoma City Oil Pool
By Roy L. Ginter

Tansill Formation West Texas and Southeastern New Mexico
By Ronald K. DeFord and George D. Riggs

Geology of Southern Part of LaBarge Region, Lincoln County, Wyoming
By A. J. Bertagnolli

Correlation of Cross' LaPlata Sandstone, Southwestern Colorado
By Marcus I. Goldman and Arthur C. Spencer

Well Logging by Radioactivity
By William L. Russell

Pre-Cretaceous Sediments in Cordillera Oriental of Colombia
By Parke A. Dickey

POSSIBLE FUTURE OIL PROVINCES
OF THE
UNITED STATES AND CANADA

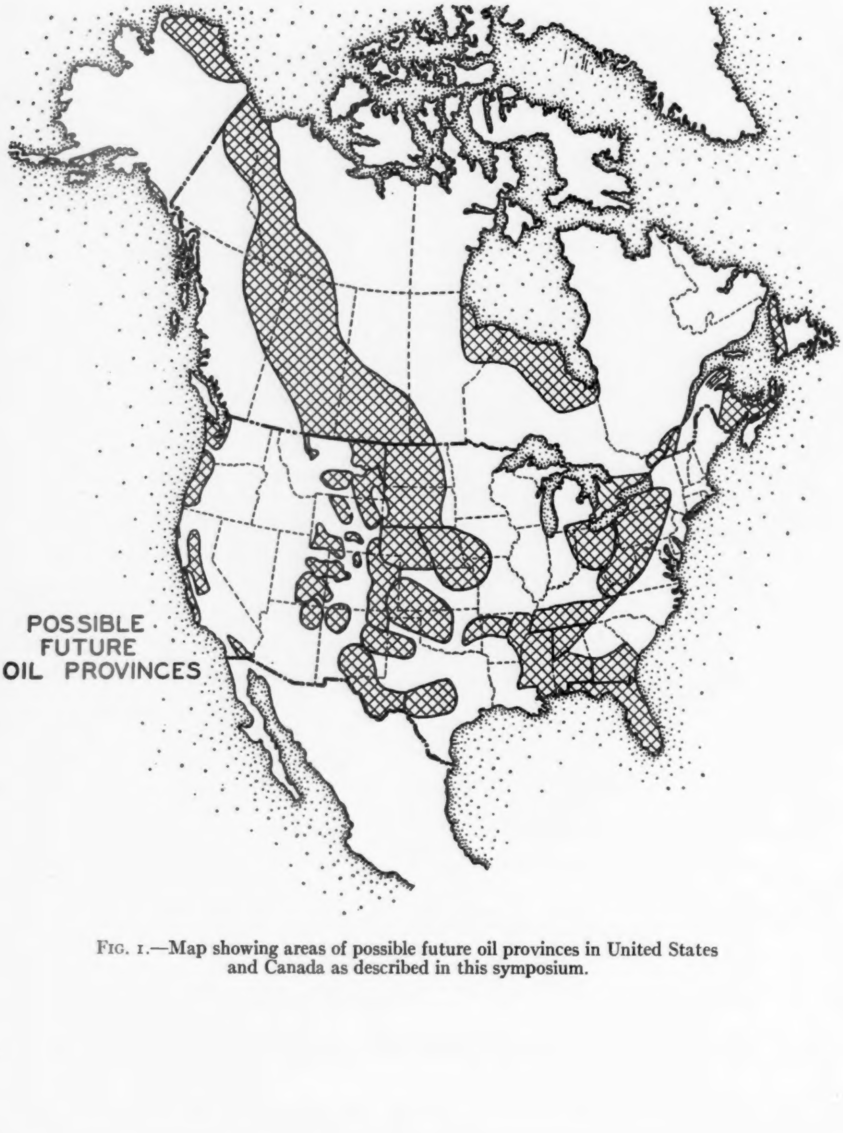

FIG. 1.—Map showing areas of possible future oil provinces in United States and Canada as described in this symposium.

POSSIBLE FUTURE OIL PROVINCES
OF THE
UNITED STATES AND CANADA

A Symposium Conducted by the Research Committee of The American Association of Petroleum Geologists, A. I. Levorsen, Chairman. Papers Read at the Twenty-Sixth Annual Meeting of the Association, at Houston, Texas, April 1, 1941, and Published in The Association Bulletin, August, 1941

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CONTENTS

CONTENTS

POSSIBLE FUTURE OIL PROVINCES OF THE UNITED STATES AND CANADA[1]

FOREWORD

A. I. LEVORSEN[2]
Tulsa, Oklahoma

The following remarks are a brief introduction to the symposium and a statement of what we are trying to do, how we propose doing it, and why we think it worth while.

WHAT ARE WE TRYING TO DO?

The purpose of this symposium is to take an inventory of the merchandise we have in our warehouse—to get an over-all picture of the undiscovered oil resources of that part of this continent north of the Rio Grande. We are dealing, fundamentally, with the philosophy of discovery—of geologic exploration. We can make such a statement, even though the articles to follow consist largely of a factual inventory of geologic data, because the discrimination we use in selecting the data is the measure of our philosophy of discovery—the measure of our geologic thinking. If we did not think a certain kind of data significant, it would not be included in our inventory.

In thinking of these undiscovered reserves, we may divide them into two general groups for the purposes of the present discussion. First, the undiscovered reserves within those producing areas where development is now active and where lease interests are large and valuable. From our present knowledge, for example, we can say that West Texas has an enormous undiscovered reserve of oil yet to be found in rocks of Ordovician, Devonian, and Silurian ages—or, because of what we know now, we can safely predict that large additional reserves will be discovered in the Tertiary Wilcox formation of the Gulf Coast states. Both regions contain many favorable, but as yet untested, areas between and below the present producing pools. Some oil has already been found in these formations and, from our knowledge of their underground distribution and character, we can be assured of discoveries in the future. Second, the undiscovered reserves of those outlying areas which have in the past been only partly explored and in which discoveries of any consequence have yet to be made. The first class might be called "probable" and the latter "possible" reserves. It

[1] A symposium conducted by the research committee of the American Association of Petroleum Geologists. Papers read at the 26th annual meeting of the Association, at Houston, Texas, April 1, 1941. Manuscripts received, May 21, 1941.

[2] Chairman, research committee. 221 Woodward Boulevard.

is only with the latter type of reserve or supply—located in the heretofore unexplored areas—that we are here concerned.

This inventory is not to be considered as quantitative in any barrel sense. Neither are we concerned with the problem of how this reserve is to be discovered. We are concerned, however, with the question: Is this undiscovered reserve much, or is it little, in terms of national needs? We will approach the question of whether it is much or little by analyzing the type of geology which is as yet unexplored. If we find there are large unexplored volumes of rocks with favorable petroleum geology, then we can logically infer that they will be, sooner or later, by some means or other, translated into large reserves of petroleum. If on the other hand we find that the unexplored territory of favorable petroleum geology is relatively small, then we would be justified in the belief that our future undiscovered reserves may be correspondingly small.

As individuals, or as oil companies, we might well be satisfied with a single oil field, a single lease, or even an interest in a producing lease—but if we are to think in terms of the industry as a whole and of the nation as a whole, then we must think in terms of provinces—areas where we may expect to find, not one pool, but rather many pools—and pools of a size which will mean something in the national economy. We propose thinking in terms of provinces in this symposium.

HOW ARE WE TO DO THIS?

The research committee has asked several geological organizations to coöperate in this inventory or survey. As an example, one of the coöperating groups is the Rocky Mountain Association of Petroleum Geologists. It has appointed a committee of seven of its members, whose job it has been to select the provinces within the Rocky Mountain region which they believe have possibilities of ultimately producing oil, to prepare sketch maps and cross sections showing the general geology, geography, and stratigraphy of the prospective provinces, and to write short articles describing the reasons for their belief that these areas have oil possibilities. Each article contains a short selected list of key references to the general geology of the area described. The more recent references are given preference, particularly if they contain bibliographies of the literature of the area.

In a like manner, nine other organizations have participated to the end that the composite result of the survey will have behind it the authority of many geologists representing State and National geological surveys, large and small oil companies, together with consulting and independent geologists.

One of the first questions encountered in thinking about these possible future oil provinces was: "What are the criteria of an undiscovered oil province?" There are about as many answers to this as there are geologists—each one has his own requirements. However, as it is necessary to begin with a set of criteria—common denominators, if you will—the following are those which have been used in analyzing the problem of our possible future provinces.

1. SEDIMENTS

If all that was known about any area was that it contained sediments, it might be considered as having chances of producing oil in proportion to the quantity of such sediments. If these sediments were marine, were variable, and were unmetamorphosed, the chances would probably be better. The volume or quantity of such sediments, in cubic miles, gives some comparative figure of the relative amounts of material with which we have to work—it does not necessarily mean, however, the relative quantities of oil which will eventually be found. The Los Angeles Basin, for example, is probably much richer than the average basin but with a much less quantity of sediments. The sediments of each area, their volume and their character, are therefore first described.

2. EVIDENCES OF OIL AND GAS

If these sediments contain evidences of oil and gas, such as seeps, showings in wells or producing fields in or adjacent to the area discussed, they are presumed to have better chances of ultimately producing commercial oil than if no such evidences are known. Furthermore, if there are known evidences of oil and gas, the question of source rocks, which is often troublesome, is automatically solved. In other words, if there is evidence of oil, then there must have been source rock, whatever it might be. The various known evidences of oil and gas in each prospective area are described as another factor which is important when estimating the chances of future production.

3. UNCONFORMITIES

Much of our present and past oil production has been found associated with unconformities. They mark the position of overlaps, variable porosity, folding, and traps. Unconformities separate the various layers of geology and many mark the place in the geologic section of greatest stratigraphic and structural change. It is at unconformities that geologists and geophysicists most commonly make their mistakes —because it is here that the changes occur which are unpredictable. The presence of a known regional unconformity within an area in-

creases the chances of finding favorable petroleum geology because it overlies and hides a new and unknown set of geologic conditions. It may not everywhere double the favorable area of prospecting but it certainly adds to it. Thus, an area with two or three known regional unconformities is two or three times more favorable to ultimate oil discovery than an area with none. Furthermore, if there is evidence in the region of pre-unconformity folding or deformation, the chances of finding oil are definitely more attractive than where there is an absence of such pre-unconformity deformation. Therefore, the unconformities which are known or thought to be present in each of the prospective areas are described as another factor favorable to oil accumulation.

4. WEDGE BELTS OF POROSITY

The reservoir rocks in many oil fields are in the form of a wedge belt of porosity. Simple examples are the East Texas field, the Bartlesville sand province, and others of this type. Even where the individual pool is located on a structural trap, a fold, or a fault, the province as a whole may be determined by the presence of a regional wedge of porosity within the reservoir rock. Thus, much of the production in West Texas, in the Midway-Sunset area of California, or in the Cromwell sand of Oklahoma is found in local folds and structures which in turn are in the vicinity of the edge of a regional belt of porosity. We therefore consider as the fourth and last favorable criterion for ultimate oil discovery, the known presence of regional wedge belts of porosity, and each area is considered from this viewpoint.

After describing each of these four criteria—which are considered, if present, as being favorable to oil accumulation—then the description of each prospective area concludes with a statement of the causes that retarded development—a mention of the adverse factors which are known or are thought to be present.

Obviously, in a symposium such as this, it is necessary that we draw boundaries around the material to be considered and the material to be omitted. These limits are more or less arbitrary. Briefly, they are the following.

1. Areas known to have a sedimentary section of less than 1,000 feet are not considered.

2. The lower limits, for the purposes of computation, are the approximate maximum economic drilling depths of the present time, that is, 15,000 feet.

3. Unexplored areas within the present oil provinces are omitted. Thus, all of Illinois and Louisiana and the present producing parts of Indiana, Kentucky, Texas, Oklahoma, Kansas, Arkansas, Wyoming, Montana, and California are arbitrarily omitted from any considera-

tion. These states all are known to have many untested possibilities for additional discoveries within and between the present producing areas—but due to the active development and to the large leasehold values which have been developed in the past, the future possibilities of these producing areas are not considered in the present survey.

4. There are many areas in which the information is so meager that no opinion one way or the other is ventured. The Great Basin region of Nevada and the region extending south into California and Arizona; the volcanic field of Idaho, Oregon, and Washington; and the Atlantic

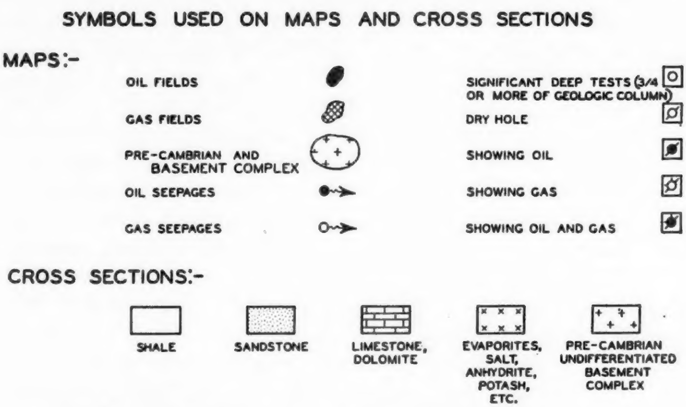

FIG. 2.—Chart showing map and cross-section symbols used.

coastal belt from New Jersey to South Carolina are examples of areas in such a classification. Sediments, evidences of oil, unconformities, and even wedge belts of porosity are known in each of these areas yet they contain adverse factors which are sufficient under the present state of our knowledge to justify leaving discussion of their prospects to some future symposium. This does not mean that it is believed commercial oil will never be discovered in such regions—for each of them may well be found to contain oil at some future time—but rather that the present state of our information is insufficient to justify an opinion.

A map showing the general geology and geography of each area and a cross section which brings out some of the chief stratigraphic and structural elements accompany each of the province descriptions. Authorship of the texts and maps, except where noted, is anonymous and represents the work of committees rather than of individuals. The areas described in the symposium are shown in Figure 1 (frontispiece). Insofar as possible, all of the maps and sections have the

same symbols, which are shown in Figure 2. Clayton Rasmussen drafted the illustrations.

WHY ARE WE MAKING SUCH AN INVENTORY?

1. In a world as topsy-turvy as this one, we believe it wise and timely to take a look at our "hole card"—to re-examine our thinking about the nature and quantity of our future supplies of oil. It is conceivable that the oil industry may be called upon at any time to discover large quantities of new oil in a short time. Certainly we must face the prospect of being called upon to continue to discover large quantities of oil over the decades ahead. Are there reserves to be discovered? Some say "no" and some say "yes." This is a problem, which it seems to us, lends itself to coöperative geologic thinking, at least in the preliminary stages, which is all we can hope to do at this time. It is with the idea of exploring the subject of our undiscovered reserves and the hope that we may develop a background of sound reason and conclusion which will have the authority of a group of scientific men—men who are students of the art of discovery—that we are attempting to focus our coöperative thought on this problem.

2. The crux of the whole oil-reserve question, from both the national viewpoint and the viewpoint of the oil industry, is in the undiscovered reserve with which to replace the known reserve as it is consumed. The 18–20 billion-barrel reserve which has been developed and which now lies underground, blocked out and ready to be produced, is undoubtedly adequate for current needs. But its continued adequacy is a function of whether we believe it can be maintained through additional discoveries down through the years ahead. We who are geologists are the only group within or without the industry who have any business attempting to estimate the undiscovered reserve, whether it is much or little, where it may occur, or how it will be discovered.

3. This survey should give us a better basis for establishing a set of criteria about what constitutes a possible oil province. We have begun with a "phantom" set of criteria which we will test by describing their occurrence in each prospective province. The stronger the development of each of the four criteria which we have chosen—sediments; evidence of oil; unconformities; and wedge belts of porosity—the better the prospects should be for ultimate discovery of oil and gas. Are these criteria adequate? Should more be added? Should they be changed in any way? Once we have developed a working set of criteria then they may be applied the world over.

These criteria of a possible future oil province are important. On them depends what we think of the future oil prospects, and what we

think of the future oil prospects will influence the making of many far-reaching policies, both political and economic. It is our purpose to translate our scientific ideas, knowledge, and experience into as accurate and honest an appraisal as we know.

4. It should result in jobs for geologists and geophysicists. As commercial geologists, we are too often concerned solely with day-to-day routine geologic work. We get into ruts of thinking—and as someone has said, the only difference between a rut and a grave is that the grave is deeper. We do not ordinarily have an over-all picture, and, as a result, when from time to time we are called upon to select new areas in which to prospect, our viewpoints are limited by our limited experience and by a lack of objectivity. Furthermore, we have often spent so much of our time trying to find what is wrong with an area that it is difficult to change our viewpoint and look for the good features. Discovery can not survive on a spirit of pessimism—it requires at least a search for what is right about an area, if not a spirit of optimism.

To those with "eyes to see and ears to hear," the symposium which follows offers a foundation for many new ideas, a stimulation to "discovery" thinking with a foretaste of the kind of exploration problem with which we will be faced, and, it is hoped, a vision of the almost unlimited amount of work waiting for the geologist.

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——, "A Résumé of Geology and Occurrence of Petroleum in the United States," *Petroleum Investigation: Hearings before a Subcommittee of the Committee on Interstate and Foreign Commerce, House of Representatives, 73d Congress, on H. Res. 441* (1934), Pt. 2, pp. 869–1081. Contains a map of the United States (Fig. 1, opp. p. 910), showing oil fields and areas now unproductive, classified with respect to their relative likelihood of yielding commercial quantities of oil.
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VOL. 25, NO. 8 (AUGUST, 1941), PP. 1440-1446, 3 FIGS.

POSSIBLE FUTURE OIL PROVINCES IN ALASKA

PHILIP S. SMITH[1]
Washington, D. C.

The potential petroleum resources of Alaska are not known and they are not predictable with an approximation of accuracy from the facts now at our disposal. At present no petroleum is being produced from any Alaska field, and in the past there has been only one commercial field. Furthermore, the production of this field was measured

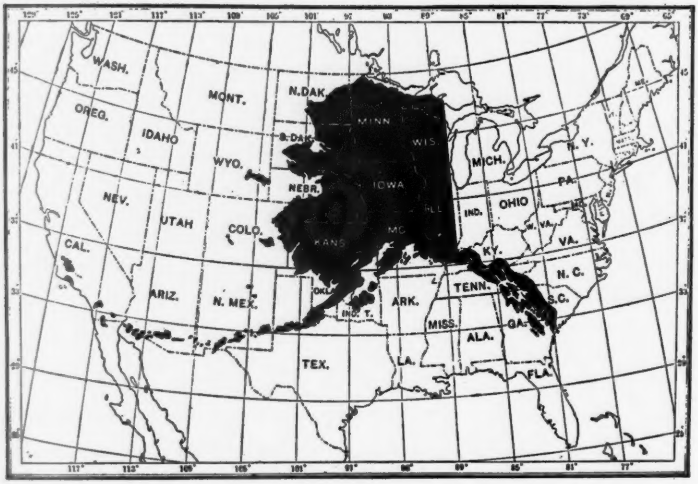


FIG. 1.—Map showing area of Alaska compared with area of United States proper.

in terms of a few thousand barrels a year and the gross value of its total production was less than three-quarters of a million dollars. As a consequence, there are few demonstrable facts on which to outline prospective areas and the conditions that will be encountered in them. Indeed, at present, although Alaska embraces an area equal to about one-fifth of the total area of the states proper (Fig. 1), more than half has not been surveyed with the degree of thoroughness regarded as adequate even for exploratory purposes. Thus, there are more than 300,000 square miles—equal to about twice the size of California—concerning which data are entirely lacking and a nearly equal area about which little more than geologic surmises are available.

[1] Chief Alaskan geologist, United States Geological Survey.

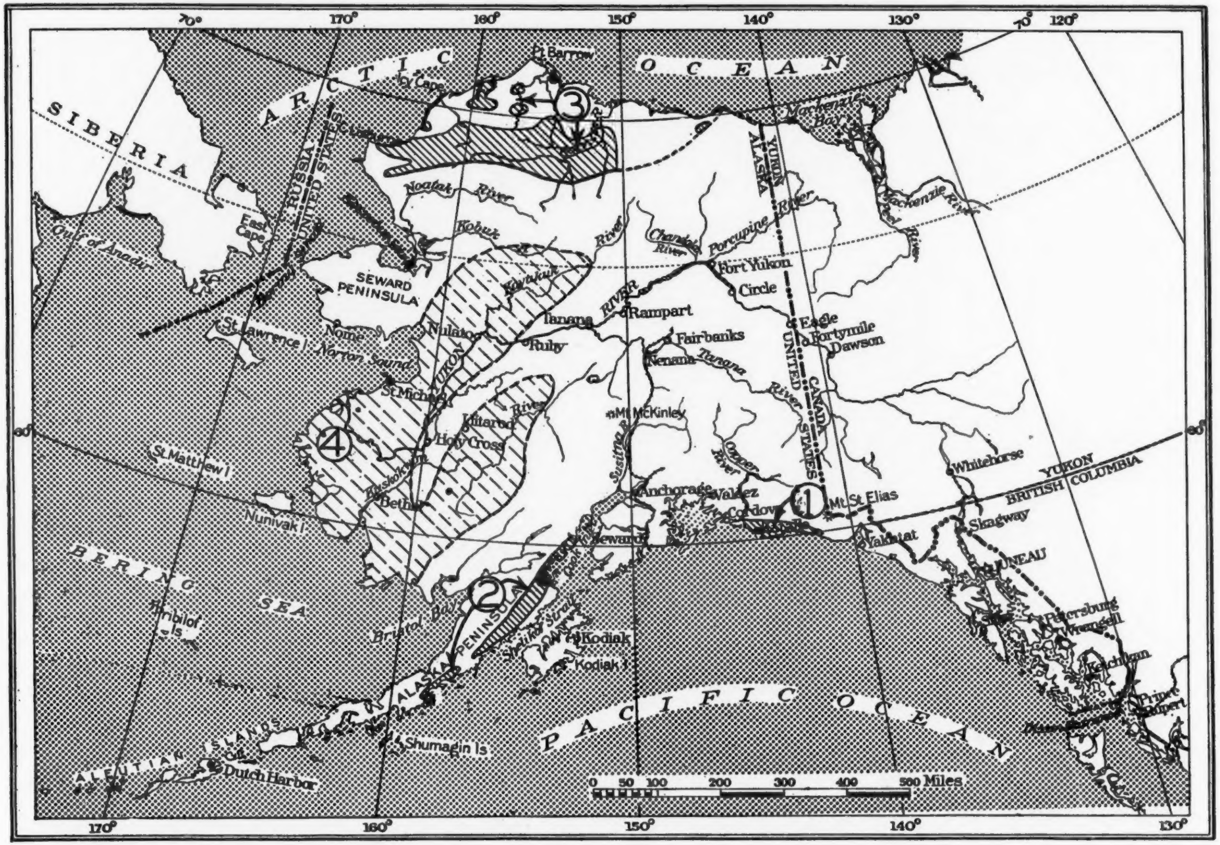
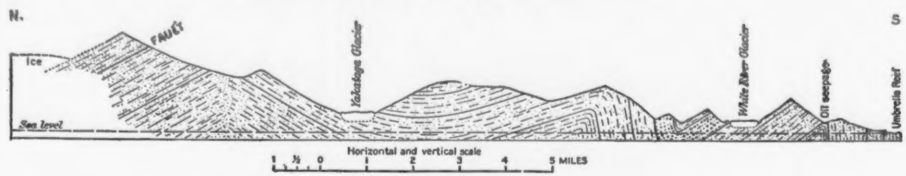
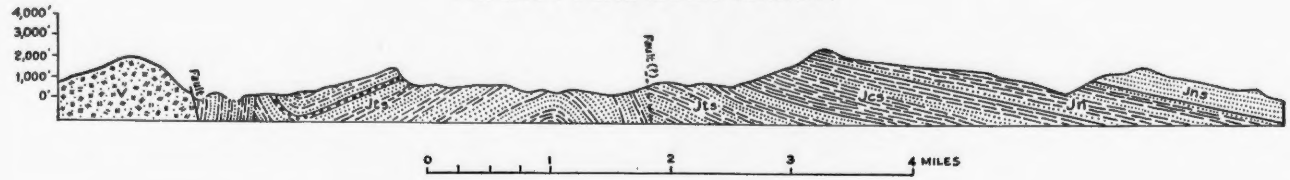


FIG. 2.—Map of Alaska showing regions favorable for oil. No. 1 and No. 2, regions patterned with diagonal lines, have Jurassic bedrock; No. 3, with the same pattern, has Cretaceous bedrock; No. 4, patterned with broken diagonal lines, also has bedrock of favorable composition and structure.

STRUCTURE IN YAKATAGA FIELD



STRUCTURE IN INISKIN BAY FIELD ALASKA PENINSULA REGION



GENERALIZED CROSS-SECTION OF NORTHERN ALASKA FROM ETIVLUK R. TO IKPIKPUK R.

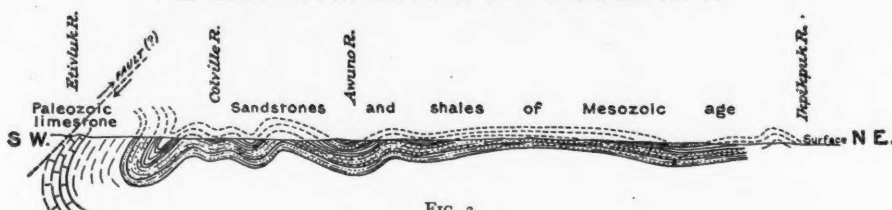


FIG. 3

In spite of the lack or indefiniteness of quantitative information about the oil resources of Alaska, there are at least three large areas in which showings of oil and definitely favorable conditions and structures have been found. These are indicated on the map and cross sections (Figs. 2 and 3) and may be conveniently identified as (1) the Katalla-Yakataga district, (2) the Alaska Peninsula region, and (3) northwestern Alaska. It is obviously impracticable here to present more than a most sketchy summary of each.

KATALLA-YAKATAGA REGION

The Katalla-Yakataga field (No. 1 in Fig. 2) is the only Alaska field that has so far afforded a commercial production of oil. The bedrock in the vicinity of the wells that have produced oil, and near the known seepages, has been identified as Tertiary and generally considered to belong in the Miocene. The Tertiary sequence has not been fully worked out, but apparently it embraces upward of 10,000 feet of strata. These rocks have been broadly as well as locally deformed, so that their major structures trend about east and west with subordinate folds and wrinkles, some of which have been broken and dislocated by faults. Martin, however, has pointed out that in parts of this field structural conditions are no more complex than those encountered in many of the California fields. None of the producing wells was as much as 2,000 feet deep and many of them were as shallow as 1,000 feet. It has by no means been proved that the oil originates in these Tertiary beds and, in fact, Martin suggests the probability that the source is to be sought in the underlying Mesozoic strata. The live oil has a gravity of 41°–45° Bé., a paraffine base, and is very low in sulphur.

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ALASKA PENINSULA

Indications of oil have long been known in the Alaska Peninsula (No. 2 in Fig. 2), having been recognized by the Russians as early as 1853. Along the east flanks of the Alaska Peninsula, stretching for a distance of more than 350 miles, are a number of separate areas in which signs of oil have been found. The physical features in each of these areas show wide differences, but in general the bedrock consists of members of the Jurassic system. On the whole the stratigraphic sequences consist of thick sections of shales with subordinate amounts

of sandstone and conglomerate. Drilling tests of certain of the more promising structures have been carried to depths of several thousand feet (8,875 feet in the Iniskin-Chinitna area; 5,034 feet in the Cold Bay area) without disclosing commercial pools, though by no means demonstrating their absence. Tests of small amounts of oil recovered in the course of some of the drilling are said to have shown a very high-grade oil with paraffine base and almost no sulphur.

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NORTHWESTERN ALASKA

In northwestern Alaska (No. 3 in Fig. 2) the only definite showings of petroleum are at a few seepages in the extreme northern part of the area, near Cape Simpson, on the Arctic Coast. Evidence as to the character of the bedrock in this place is not entirely unequivocal, but apparently the bedrock is part of the Upper Cretaceous series, consisting dominantly of sandstone and shale. A possible source of this oil is suggested by the finding of oil shales in the Cretaceous sequence approximately 160 miles south of the seepages. The Cretaceous section in this area has been estimated as being possibly as much as 20,000 feet thick and comprises at least two thick units of marine sediments and one or more terrigenous units with thick coal beds. The structural conditions at many places within the area occupied by the Cretaceous rocks in northwestern Alaska are excellent for trapping and retaining any oil that may have migrated in them, as the rocks have been folded into numerous anticlines trending east and west or more or less parallel with the buttressing mountains on the south. Many of these structures have not been much fractured. A tract embracing 30,000 square miles of this potential field has been reserved by the Government as a naval petroleum reserve.

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WESTERN ALASKA

In addition to these three areas in which definite showings of oil have been recognized, there are several large tracts in which the composition and structure of the bedrock are such as to afford some inducement for exploration by the seeker for deposits of oil. The principal area of this sort is the irregular expanse of country extending from the delta regions of the Yukon and Kuskokwim rivers northeastward to embrace other parts of these river valleys and the valleys of the Koyukuk and Kobuk rivers. The approximate limits of this area are shown (No. 4 in Fig. 2) in the western part of Alaska. Throughout most of this tract the bedrock, so far as known, consists dominantly of sedimentary members of the Cretaceous or later systems. Numerous intrusive and extrusive igneous rocks in places cut through or overlie the sedimentary beds. As a result, the continuity of the older rocks is by no means uninterrupted. As has been stated, no signs of petroleum have been reported in the area, and the principal justification for mentioning it as worthy of investigation for oil, is the fact that in places it contains a thick series of sediments which are deformed so as to produce structures capable of trapping oil, and yet the rocks have not been metamorphosed to such an extent as would destroy oil that may have originated in them.

OUTLOOK FOR FUTURE

From the foregoing statements it is evident that even the most promising of the prospective oil areas of Alaska have not been tested adequately. The reasons for this are obvious. The districts are all remote from the more settled areas and markets, so that costs are high, transportation facilities meager or lacking, and local supplies of equipment or labor non-existent. Climatic conditions are adverse. The low temperatures make outdoor operations a real hardship during the winter months; the short open season, which sharply limits certain types of activities, and the long period of winter darkness, combine to present handicaps to development that are not faced in more southern latitudes. Ignorance of the geologic conditions under which the oil occurs and which will be encountered in the search, while in part the same as must be faced in opening any new fields, is perhaps even more serious because of the more than ordinarily difficult obstacles to be overcome, and the many new technical problems that lie outside the experience of most oil geologists or operators.

In spite of these various deterrents to development, the writer feels that in the minds of many persons, the hazards are over-emphasized

and do not differ greatly in degree from those faced and overcome in the search for, and development of, oil-producing areas in many parts of the world. The bug-bear of Alaska cold is really far less terrifying than the enervation and unhealthfulness of the tropics, with their danger of microscopic and macroscopic animal pests, and the remoteness of some of the areas in Alaska is actually no greater than that of some of the areas in South America and Oceanica, which are now contributing their floods of oil.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 25, NO. 8 (AUGUST, 1941), PP. 1447-1456, 4 FIGS.

POSSIBLE FUTURE OIL PROVINCES IN WESTERN CANADA

ALBERTA SOCIETY OF PETROLEUM GEOLOGISTS[1]
Calgary, Alberta

GENERAL STATEMENT

The chief possibilities for development of oil fields in western Canada lie in the Great Plains and Foothills provinces constituting a great triangular area, with its base 800 miles in width along the International Boundary, extending northwestward 1,600 miles to the Arctic Ocean at the Alaska Boundary (Fig. 1). The area included is approximately 650,000 square miles, and is underlain by 1,000 to 13,000 feet—estimated average of one mile thickness—of sediments, largely marine in origin. The gross volume of these sediments approximates 650,000 cubic miles. Within this region as a whole, the sedimentary record is fairly complete from earliest Paleozoic through the Mesozoic and Cenozoic, although important gaps occur.

This region is bounded on the west by the Rocky Mountains and on the east by the pre-Cambrian shield. The structure is basin-like, with the Alberta syncline occupying the deepest part. The axis of this asymmetric trough lies immediately east of the foothills in southern Alberta, but diverges eastward farther north. The eastward, mountain-building thrusts of the Laramide revolution gave rise to the overthrust fault blocks of the Rockies and the folded and faulted foothills belt on the east, and also caused the downwarping of the Alberta syncline which is generally terminated by faulting along the west flank. It is believed that the axis of the pre-Laramide basin, which was the final phase of the Cordilleran geosyncline, lay some distance west of the Alberta syncline. The sedimentary section as a whole thickens gradually from east to west across the plains and foothills, and, in the case of certain formations, very great thickening occurs in the front ranges of the mountains and farther west. It is generally accepted that the axis of the geosyncline, beginning in pre-Cambrian time, when it lay west of the present site of the Rockies, underwent progressive shifting eastward until the basin was finally destroyed by the Laramide revolution.

[1] Committee consists of J. B. Webb, Anglo-Canadian Oil Company, chairman: J. S. Irwin, consulting geologist; E. H. Hunt, McColl-Frontenac Oil Company Limited; W. D. C. Mackenzie, Royalite Oil Company, Ltd.; S. E. Slipper, Canadian Western Natural Gas Company; R. V. Johnson, consulting geologist; J. O. G. Sanderson, consulting geologist; J. O. Galloway, Standard Oil Company of British Columbia Limited; and Max W. Ball, Abasand Oils, Ltd.

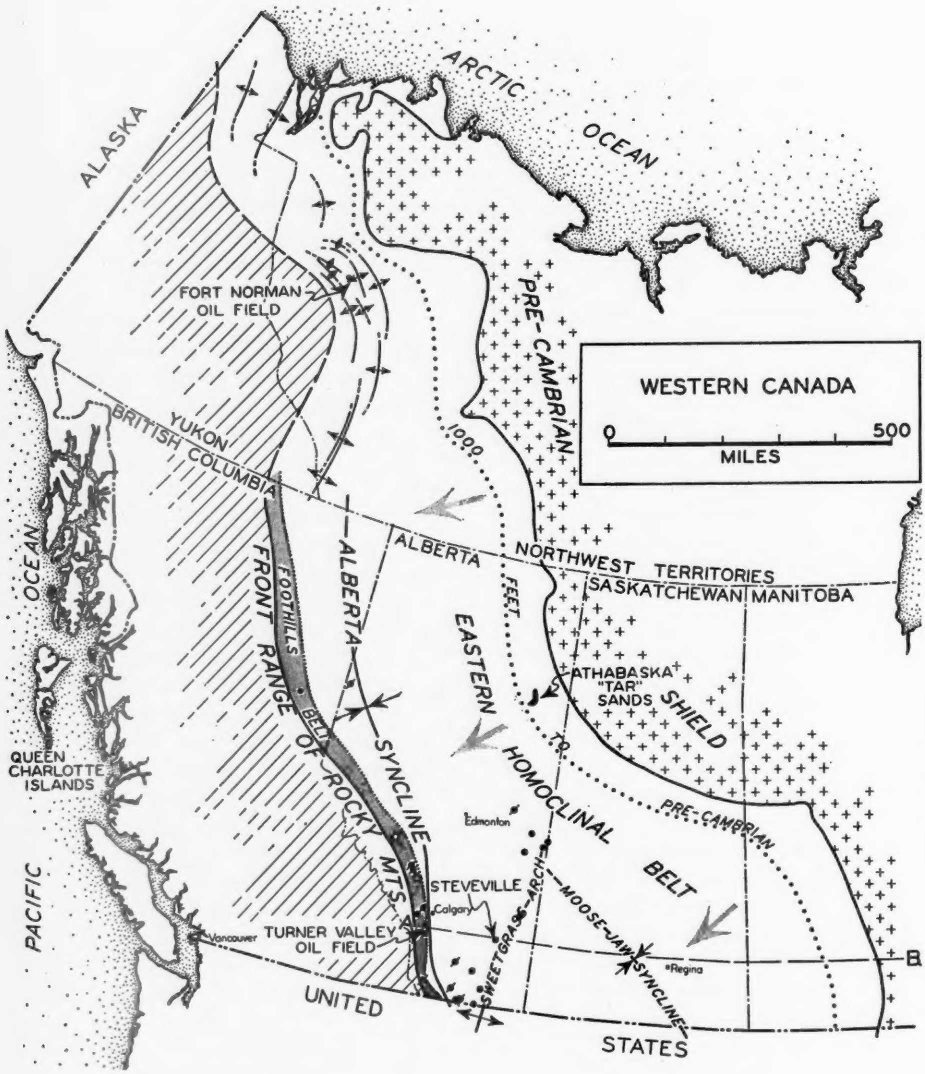
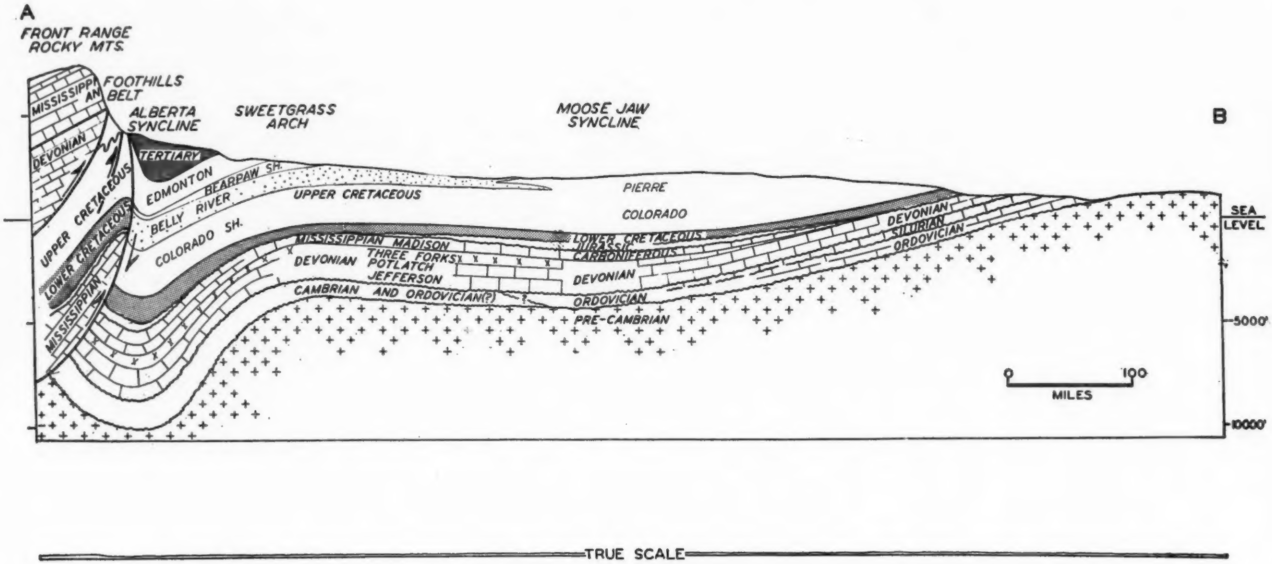


FIG. 1.—Map showing general features of western Canada. Main area described lies between Front Range of Rocky Mountains on west and dotted line marking depth to pre-Cambrian of 1,000 feet on east.



WESTERN CANADA

FIG. 2.—Generalized structure section across southern Plains region of western Canada. Location of section shown in Figure 1.

STRUCTURAL DIVISIONS

From west to east, in the southernmost part of this great belt, the following structural units occur.

1. Front ranges of Rocky Mountains
2. Foothills belt
3. Alberta syncline
4. Sweetgrass (or Bow Island) arch
5. Moose Jaw (or Regina) syncline
6. Eastern homoclinal belt
7. Pre-Cambrian shield

The general relationships of these broad features are indicated on the accompanying map (Fig. 1) and cross section (Fig. 2), and, as they are all simply northward continuations of Montana and North Dakota structures, are not further described. In central Alberta, due to the disappearance of the Sweetgrass arch and the Moose Jaw syncline, the structure becomes simplified, but farther northwest, in the vicinity of the Liard River, the exceptional structures of the Mackenzie River district begin to appear. These consist of a series of arcuate, anticlinal, thrust-faulted, outlying mountain ranges, indicated on the map by numerous anticlinal axes, which disrupt the continuity of the Alberta syncline. These mountains appear to be related to a great overthrust salient of the Rocky Mountains proper which constricts, seriously, the favorable belt of territory in this part of the region. Farther northwest, there is less folding and the belt widens again, with a slight plunge northwest.

GENERAL CHARACTER OF SEDIMENTARY ROCKS

On the Sweetgrass arch, a drilled section of approximately 6,100 feet which reached the igneous basement rocks, presumably pre-Cambrian, is composed of 50 per cent shales, 30 per cent limestones and dolomites; 15 per cent sandstones, and 5 per cent evaporite, the latter chiefly anhydrite. About 80 per cent of this section represents marine deposition. On the west, near the axis of the Alberta syncline, a hole was drilled nearly 9,000 feet in depth and a fair estimate may be made as to the character of an additional 4,000 feet of underlying sediments. This 13,000-foot section includes about 50 per cent marine and 50 percent non-marine sediments, and, compared with the deep hole at the east, the percentage of sandstone and limestone is slightly greater with a corresponding decrease in the amount of shale. A great thickness of fresh-water Upper Cretaceous and Tertiary present in the Alberta syncline is missing on the Sweetgrass arch, due to erosion and (or) non-deposition. In the Moose Jaw syncline in south-central Saskatchewan, combined drilled sections have penetrated 5,500 feet of sediments, 95 per cent marine in origin, chiefly shales, with about 10 per

cent limestones, 5 per cent sandstones, and 1 per cent evaporites (anhydrite and salt).

In the outlying mountain ranges of the Mackenzie River district, exposed sections of strata ranging from Upper Devonian down to the base of the Cambrian, which is in contact with pre-Cambrian sediments, measure between 6,000 and 7,000 feet in thickness. The generalized section consists of nearly 55 per cent shale, 30 per cent limestone and dolomite, and 15 per cent sandstone. The shales contain a very small amount of gypsum in places. An additional thickness of more than 500 feet of Cretaceous sandstones and shales, chiefly marine, overlies the Devonian beds in the synclinal areas between ranges.

UNCONFORMITIES AND OVERLAPS

The great unconformity at the base of the Paleozoic is well known, but much more significance is attached to unconformities or disconformities within the Paleozoic and lower to middle Mesozoic formations. Cambrian formations which occur along the front ranges, beneath the Alberta plains and far northwest along Mackenzie River, do not appear along the edge of the pre-Cambrian shield. They are overlain by Middle Devonian formations in southern and western Alberta. Eastward both Ordovician and Silurian formations appear, the former evidently overlapping the Cambrian and forming the basal Paleozoic in contact with the pre-Cambrian in Manitoba. Northwestward, also, Ordovician and Silurian formations appear between Cambrian and Middle Devonian beds, but neither Ordovician nor Silurian occurs in some places along the edge of the pre-Cambrian, where Middle Devonian beds overlap onto the shield. This fact, together with the entire lack of Lower Devonian, suggests a considerable unconformity, probably the most significant within the Paleozoic series, at the base of the Devonian.

The most important break within the entire section is that between the Paleozoic and Mesozoic. In the southern foothills and plains, Jurassic strata overlie Mississippian limestones, with the Jurassic, on the plains, disappearing northward and Lower Cretaceous overlying the Paleozoic. Post-Paleozoic erosion caused truncation of the Mississippian eastward from the front range and northwest, north, and east from the southern plains. The Lower Cretaceous (also Jurassic of southern Manitoba) overlaps onto Devonian in these directions, and in places the Lower Cretaceous actually extends across the Paleozoic completely and lies directly on the pre-Cambrian.

The evidence points to further uplift and erosion in early Lower Cretaceous time, indicated by the widespread overlap at the base of the Blairmore formation.

POSSIBLE OIL HORIZONS

Drilling tests to date and studies of the Paleozoic in outcrops do not lend much hope of finding oil in the formations below the Devonian. However, great interest attaches to the Devonian, particularly the Upper Devonian, since it has a fairly widespread petroliferous or bituminous character in outcrops and yields commercial production at Fort Norman in the Mackenzie River district; some slight production at Moose Mountain; showings at Clearwater and Prairie Creek in the southern foothills; and at Steveville on a branch of the Sweetgrass arch. The upper Mississippian limestone (Madison of the southern plains and Rundle of the foothills) is the source of Turner Valley production in the foothills and the recent discovery at Steveville. Considerable encouragement has been encountered in the Madison limestone at several tests of structures in the Sweetgrass arch area in southern Alberta. Oil accumulation may occur in porous zones within the uppermost Madison limestone or in the weathered, very cherty ("chat") zone at the top of this formation.

Basal Jurassic (Ellis) sands, also the basal Blairmore (Lower Cretaceous) or Sunburst and related sands have yielded some slight production in the southern Alberta plains. The Dalhousie sandstone production of Turner Valley occurs at the base of the Blairmore, and the Home sandstone production occurs 300 feet above the base.

Heavy oil is produced in small quantities from sands near the top of the Lower Cretaceous in east-central Alberta at the Wainwright, Vermilion, Dina, and Lloydminster (Alberta-Saskatchewan) fields. These fields are related to local, nose-like structures, generally believed to lack closure, located on the eastern homoclinal belt, and probably accumulation depends chiefly on stratigraphic traps.

The great Athabaska tar sands deposit occurs in the lower part of the Lower Cretaceous. This exceptional oil occurrence is dealt with in a separate chapter.

Gas production and good showings of oil have been encountered in various sands of the Blackleaf member of the lower Colorado shale in southern Alberta and higher sands of the Upper Cretaceous have yielded good gas fields.

EXPLORATION FACTORS

Structures are of very low relief and glacial overburden is generally heavy on the plains, factors which retard exploration considerably. Lack of local structural closure is general and has dampened the enthusiasm of the wildcatter about some areas. Geophysical methods have yet to prove their practicability, although their use is increasing.

Several favorable anticlines in the foothills have been tested or are in process of being tested, but without, so far, locating another Turner Valley. The complications of thrust faulting present a baffling problem which continues to be the chief hazard in foothills wildcatting.

Much of the territory is favorable for exploration but distance from markets renders it unattractive at present.

OTHER AREAS OF POSSIBLE FUTURE INTEREST

Space allows mere mention of the following areas: (1) the Flathead River district, southeastern British Columbia, west of the Rocky Mountains, where active oil seepages occur but deep drilling has been unsuccessful; (2) the Fraser River Delta, near Vancouver, B. C., where a Tertiary basin of considerable depth occurs and drilling has been carried to about 5,000 feet without success; and (3) Queen Charlotte Island, B. C., where oil seepages and oil shales occur and a shallow well drilled many years ago is reported to have had oil and gas showings. These occurrences are evidently in Jurassic formations.

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NORTHERN ALBERTA OIL SANDS[2]

The oil sands of northern Alberta constitute a separate and unique oil province. They have an area of 10,000 to 30,000 square miles, range from a few feet to 225 feet in thickness, have a probable volume of 35 to 100 cubic miles, are saturated with from 1 to 25 per cent of oil by weight, and are estimated to contain at least 100 billion barrels of oil.

[2] The so-called "Athabaska tar sands" constitute the largest known deposit of oil in the world. Due to their large size, the unique manner in which they are found, and to their immense economic importance in any future appraisal of oil resources of this continent, a separate description of these interesting deposits is here given.

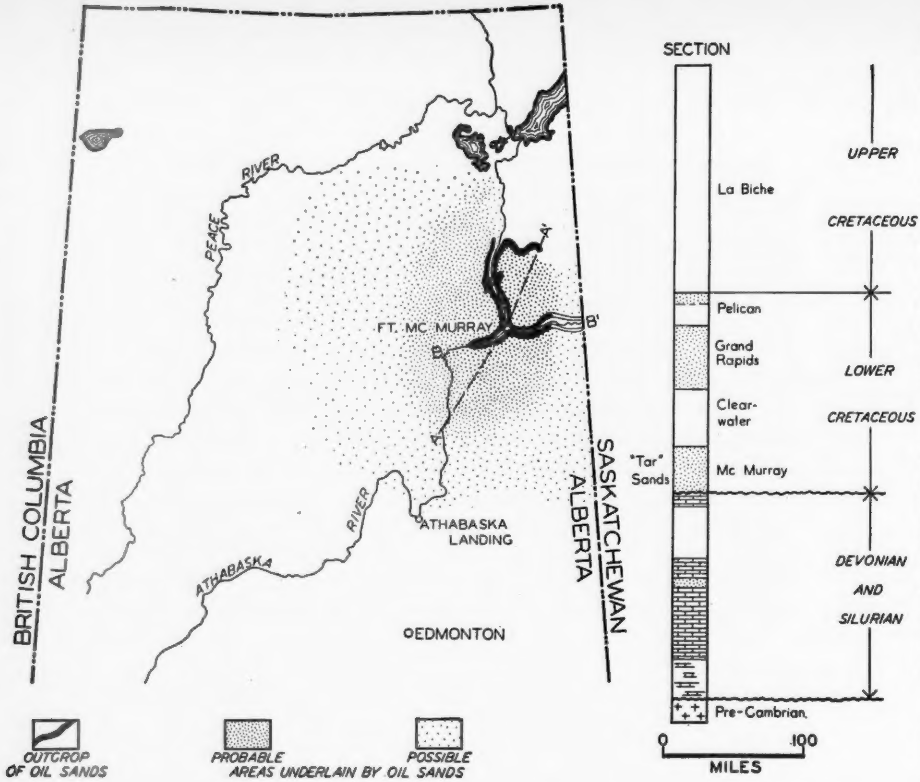

FIG. 3.—Map showing general features in vicinity of Athabaska River "Tar sands" of northern Alberta.

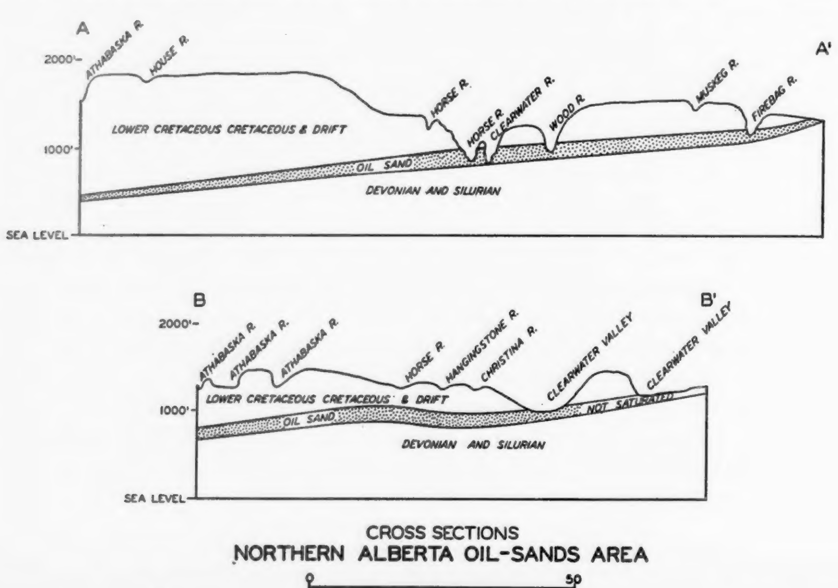

FIG. 4.—Structure sections showing underground relations across northern Alberta oil sands area.

They constitute the McMurray formation, correlated as basal Lower Cretaceous, and lie without angular unconformity on a floor of base-leveled Devonian. They are of continental origin and appear to be a great delta swept off the pre-Cambrian shield on the east into the margins of a Lower Cretaceous sea. Overlying them are 1,000 to 1,800 feet of Lower and Upper Cretaceous shales and sandstones. Immediately above them is the Clearwater shale, 275 feet thick, and above this the 280-foot Grand Rapids sandstone formation, which shows no oil saturation.

The beds dip southward and westward away from the pre-Cambrian shield at 3 to 8 feet to the mile. A broad north-south arch crosses one part of the area, and is probably paralleled by a shallow trough, but the dips are only 3 or 4 feet to the mile. The only other known structures are local "rolls" in the Devonian, in which the basal oil sands participate. These have a structural relief of less than 50 feet and widths of less than half a mile, but some nearer the shield are reported to be as much as 200 feet high, and to show dips up to 20°.

The oil is heavy, viscous, tarry, crude. Formed and remaining in rocks that have had little or no dynamic activity, and in consequence having escaped the pressures and heat to which oils in folded rocks have been subjected, it is obviously a virgin oil that has been converted only a short way beyond the asphalt stage. It is extremely sensitive to heat; in an A.S.T.M. distillation, cracking begins before the kerosene fraction has distilled over. When subjected to moderate heat for a reasonable period the whole oil changes from 10° A.P.I. to 20°–22° A.P.I., without the formation of free carbon. After such a digestion the oil fractionates like any other oil, and refines readily to a complete line of products.

The oil is not a pore-space filling in the sand, but is in the form of a film enveloping each sand grain. It is the sole cementing material of the sand; its removal leaves the sand as free as that on a beach. Because of this relationship to the sand grains and because of its viscosity the oil can not be produced from wells. To recover the oil the sand must be mined and the oil distilled out, dissolved out, or washed out with hot water. The hot-water method is the most practicable and economical, and is the one now being put into commercial practice.

More than 99 per cent of the deposit is too deeply buried for mining under present-day conditions. The only workable deposits are the benches along the valley walls of Athabaska River and some of its tributaries, where they have cut through the overlying beds and into or through the oil sands. The minable benches are estimated to contain 500 million to a billion barrels of oil.

Until 1923 the sands were too remote from rail transportation for commercial development. After a railroad reached the center of the exposed area, exploration had to await the development of an economical hot-water separation process. Such a process has now been developed and demonstrated. A plant with an estimated capacity of 350 barrels a day, complete with mining equipment and refinery, is now successfully undergoing its final tests, and is expected to be in commercial operation by the time this paper is presented. This will mark the beginning of commercial oil production from this huge and unique reserve.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 25, NO. 8 (AUGUST, 1941), PP. 1457-1468, 8 FIGS.

POSSIBLE FUTURE OIL PROVINCES IN PACIFIC COAST STATES

PACIFIC SECTION OF AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS[1]
Los Angeles, California

OREGON

The Coast Range of Oregon is formed by a gently dipping northerly trending geanticline in contrast to the northwesterly and more steeply dipping folds of western Washington.

Organic marine shales, possible source beds for petroleum, are mostly confined in Oregon to the comparatively thin shales of the lower Oligocene and lower Miocene. These shales crop out on the western and northeastern margins of the Coast Range but are not present at the summit, with the possible exception of the extreme north end of the range. Upper Eocene massive sandstones and some shale of marine, estuarine, and continental origin form the crest of the range. Similar sediments of middle and lower Eocene age with associated volcanics in the lower part crop out at the southern end of the geanticline. Exposed beneath these are deposits Lower Cretaceous in age.

The most favorable areas for future exploration are the anticlines in the Coast Range and possible buried structures in the valleys between the Coast and the Cascade ranges. However, the lack of sufficient source beds, absence of a single active oil seep in Oregon, and diabase dikes, which are especially numerous in the northern half of the Coast Range, all are unfavorable features.

The only known oil seeps in either Washington or Oregon are located in the vicinity of Hoh Head in Washington. The two small gas fields at Bellingham and Rattlesnake Hills contain only methane which appears to be a product of continental Eocene beds in which there is nothing to indicate that oil may be present in either area.

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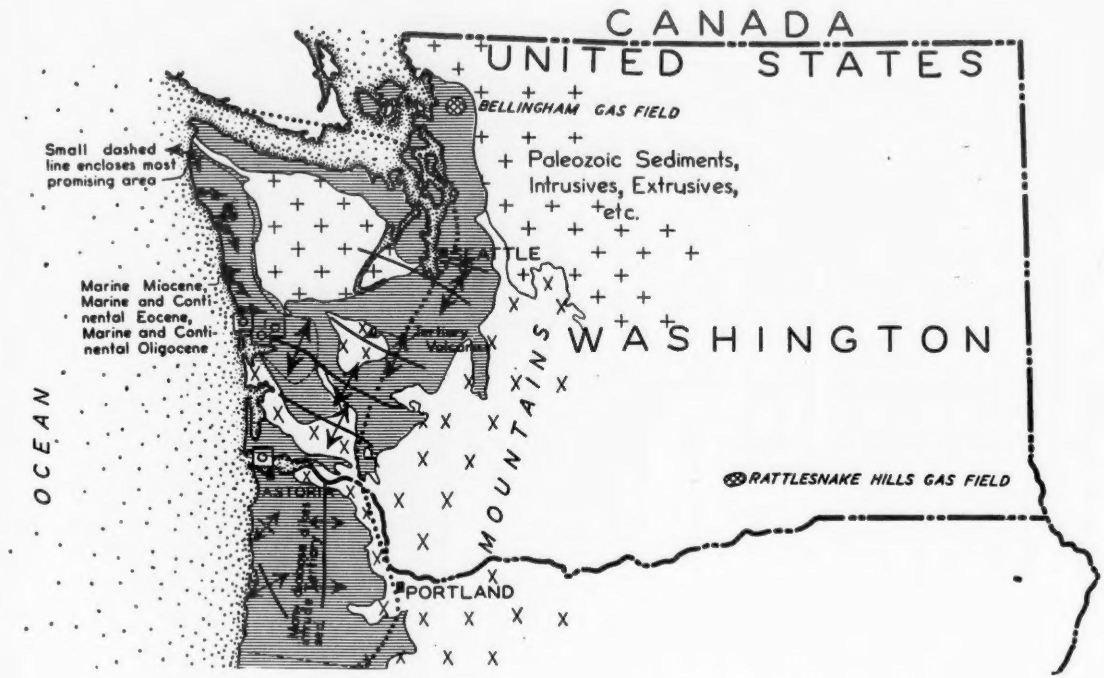
[1] Committee consists of E. W. Galliher, chairman, Barnsdall Oil Company; H. K. Armstrong, consulting geologist; Albert Gregersen, The Texas Company; Max L. Kreuger, Union Oil Company; Graham B. Moody, Standard Oil Company of California; Earl B. Noble, Union Oil Company; and R. T. White, Barnsdall Oil Company.


CANADA
UNITED STATES
BELLINGHAM GAS FIELD
Paleozoic Sediments, Intrusives, Extrusives, etc.
SEATTLE
WASHINGTON
MOUNTAINS
Small dashed line encloses most promising area
Marine Miocene, Marine and Continental Eocene, Marine and Continental Oligocene
OCEAN
ASTORIA
PORTLAND
RATTLESNAKE HILLS GAS FIELD

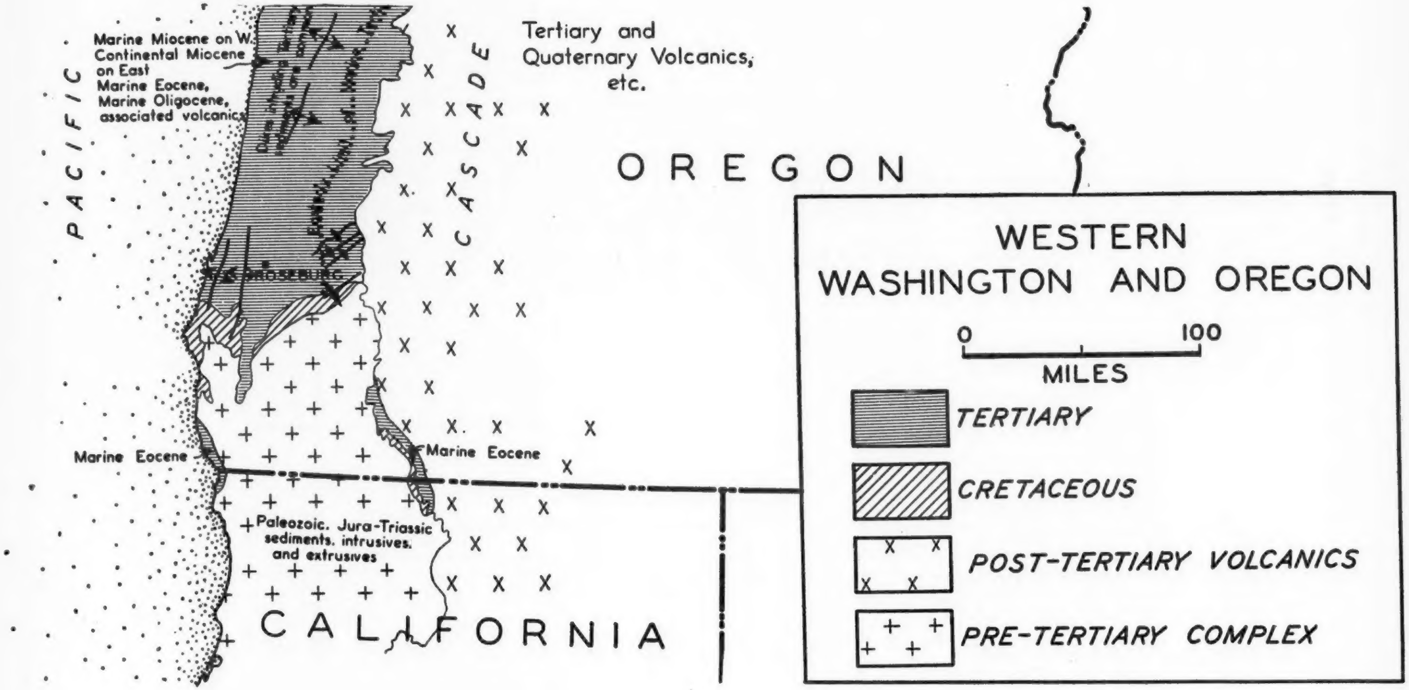


FIG. 1.—Map showing general features in western Washington and western Oregon.

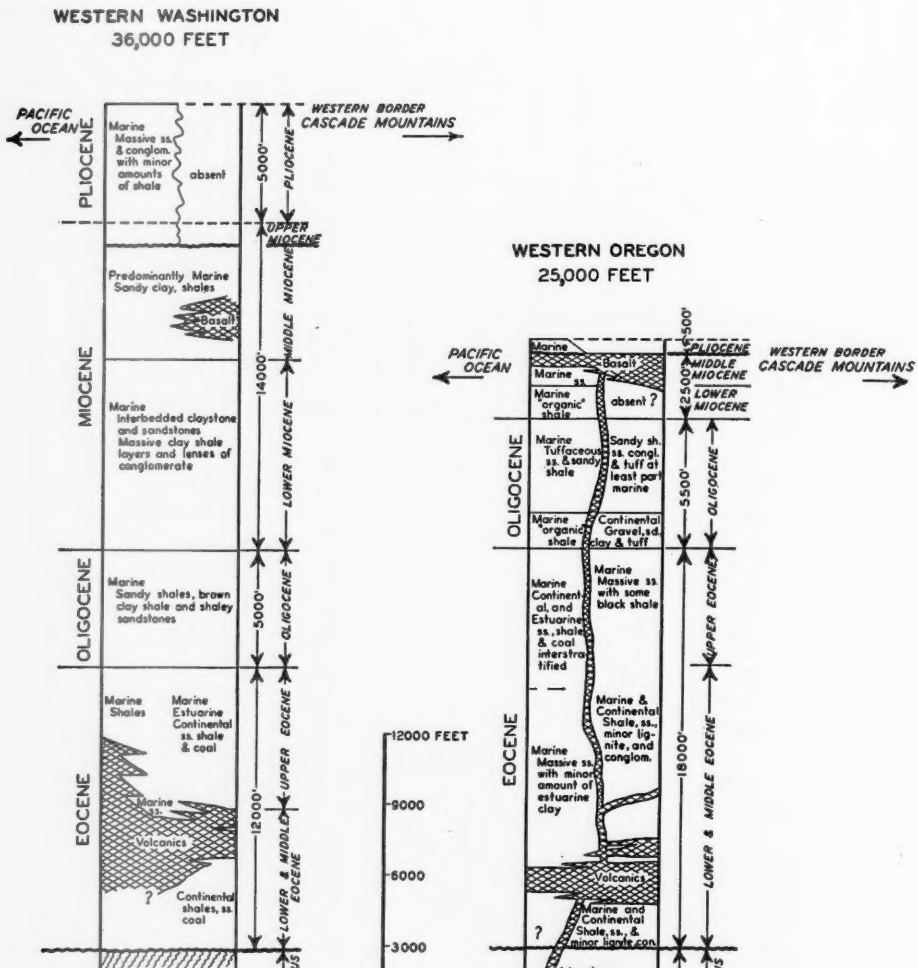


FIG. 2.—Generalized geologic column in western Washington and western Oregon.

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WASHINGTON

The thick section of Metchosin volcanics (middle Eocene) forms the base of the section in western Washington and is exposed at the crest of all of the major anticlines indicated on the map. Oligocene and lower Miocene organic shales of the Grays Harbor area make it a likely area to prospect, although a number of wells have penetrated this section down to the middle Eocene lavas without finding petroleum. Oil seeps and wells yielding a small amount of high-gravity oil on the Hoh River, on the western border of the Olympic Peninsula, from Miocene and Oligocene sediments, present the most positive indications for future exploration. Strong petroleum gas odors, locally called "smell muds" by the Indians, rise from the sediments in many places from Grays Harbor north nearly to Cape Flattery.

Glacial till in the Puget Sound area; heavy precipitation with the consequent luxuriant growth of vegetation and deep soil weathering; numerous volcanic dikes in Coast Ranges of Oregon; and lack of positive indications of oil, with the exception of the western margin of the Olympic Peninsula—these are the chief reasons which have limited exploration for oil in Oregon and Washington.

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CALIFORNIA COASTAL EMBAYMENTS

The provinces grouped together as the California coastal embayments include the remnants of Tertiary deposits in the vicinity of Humboldt Bay, Point Arena and Point Reyes, and the larger area generally spoken of as the Salinas Basin extending from Half Moon

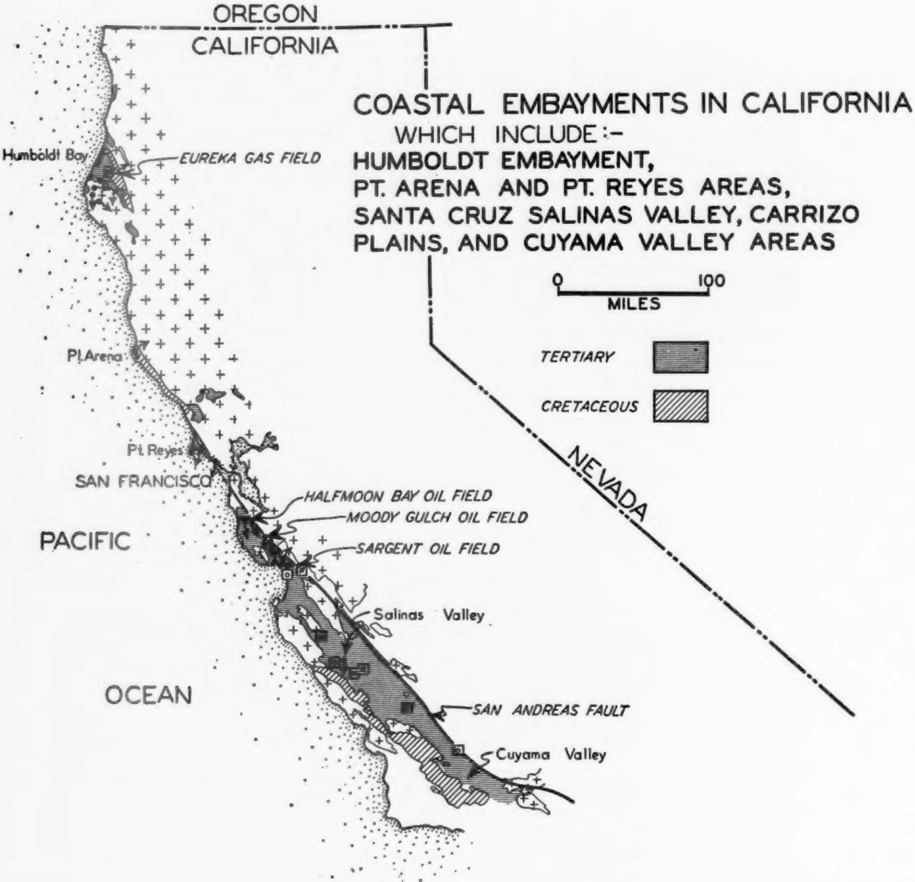

FIG. 3.—Map showing general features of coastal embayment areas in California. Areas described are cross-hatched.

Bay to Cuyama Valley. Altogether, they cover approximately 3,200 square miles.

The areas have in them a relatively large number of anticlinal structures, most of which are fairly well compressed and faulted. Half a dozen wells located on favorable structures have penetrated about three-fourths or more of the Tertiary section which averages more than 6,000 feet in thickness and ranges as high as 15,000 feet.

About 80 per cent of the section consists of marine beds whose lithologic nature is similar in various areas yet locally variable as the beds reflect the different environments—marine or brackish—under which they were deposited. The Pliocene beds are largely shale and siltstone, the upper Miocene mainly diatomaceous or so-called siliceous shale with intercalated arkose. Middle and lower Miocene have well developed shale sections grading locally to coarse textures toward old crystalline basement and Cretaceous basement shore lines. The southeast end of the Salinas Basin is marked by a development of shallow-water marine sediments in the middle and lower Miocene.

Evidences of oil and gas are numerous. Oil seeps and tar sands have been recorded in all the embayments from Tertiary and Mesozoic rocks; many of the seeps are active. Several wells that have penetrated the middle and lower Miocene have had showings of oil or gas. Three very small oil fields in the Salinas Basin are producing from Pliocene, Miocene, and Oligocene sediments; the Humboldt area contains a gas field of minor importance producing from Pliocene beds.

To the present, exploration drilling has been concentrated on favorable structures that have been relatively easy to map. The lack of commercial production, resulting from such prospecting, has given the area a rather unsatisfactory aspect.

Unconformities and facies changes within the sedimentary rocks are numerous and have been given some attention in exploration work in the past; however, detailed study of every possible stratigraphic variation, which might result in oil traps, remains to be done.

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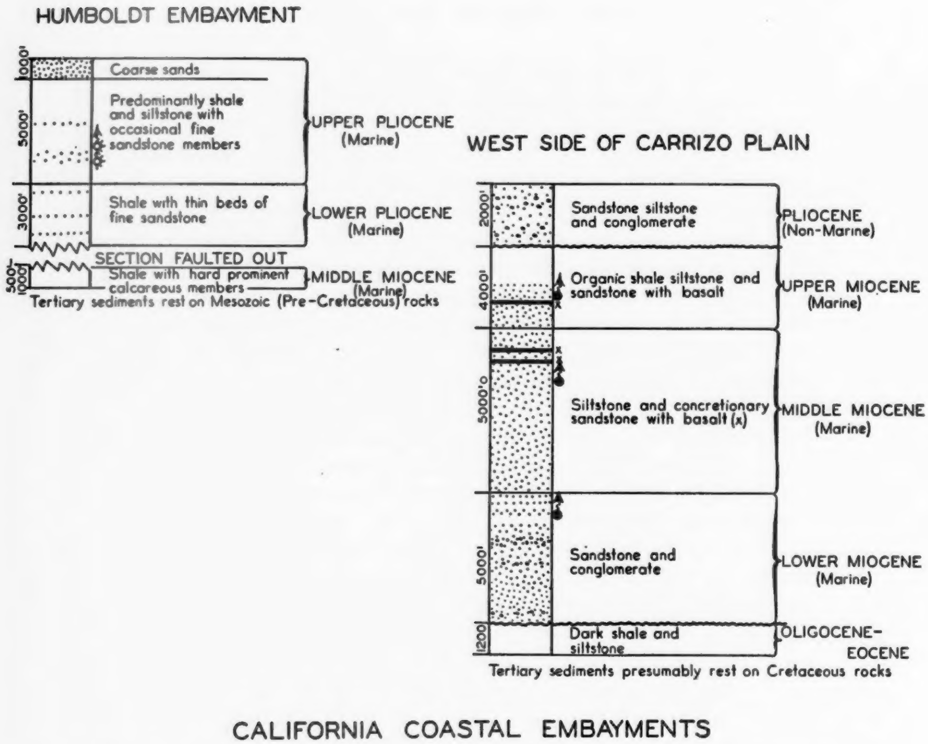

FIG. 4.—Geologic columns in Humboldt Embayment and along west side of Carrizo Plain, western California.

SACRAMENTO BASIN, CALIFORNIA

			COAST RANGE AND MARGINS OF VALLEY	VALLEY FLOOR
TERTIARY		PLIOCENE	8500' CHIEFLY NON-MARINE	3850' NON-MARINE
		MIOCENE	6500' MARINE & NON-MARINE	
		EOCENE	7500' MARINE & ESTUARINE	4350' MARINE
CRETACEOUS	UPPER	CHICO SERIES	15,000' MARINE, DELTAIC	7350'+ MARINE
	LOWER	SHASTA SERIES	12,500' TO 18,000' MARINE, DELTAIC	NOT KNOWN
JURASSIC	UPPER	KNOXVILLE	16,000' TO 20,000' MARINE, DELTAIC	NOT KNOWN

NOTE: THICKNESSES ARE IN FEET.

FIG. 5.—Table of formations encountered in Sacramento Basin, California.

SACRAMENTO BASIN, CALIFORNIA

The area called the Sacramento Basin includes not only the sediments exposed in the Sacramento River drainage but also those exposed in the San Joaquin Valley drainage as far south as Coalinga and Fresno.

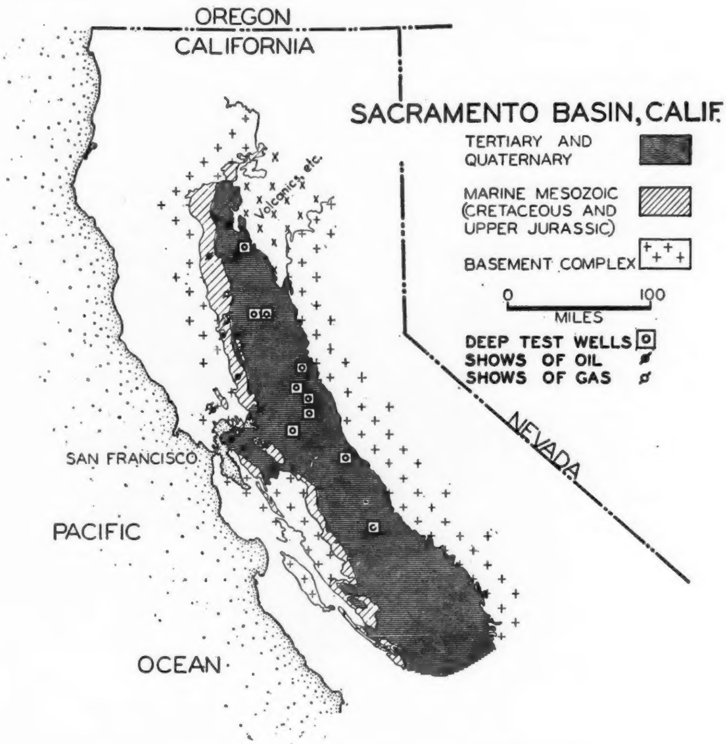

FIG. 6.—Map showing general features and location of significant test wells in Sacramento Basin, California.

The approximate area covered is 22,000 square miles and the total stratigraphic thickness of sediments that may be measured around the margin of the basin totals more than 65,000 feet. It is practically the only area on the West Coast in which the Mesozoic rocks are being given much attention, not only because of their present commercial gas production but also because of their future oil and gas possibilities.

Evidences of oil and gas in the form of outcrop seepages are numer-

ous with gas seepages outnumbering oil about two to one. In the wells that have been drilled and had showings, but are unproductive, those having oil showings were nearly as numerous as those having gas showings. The result of drilling to date has been the discovery of eight gas fields.

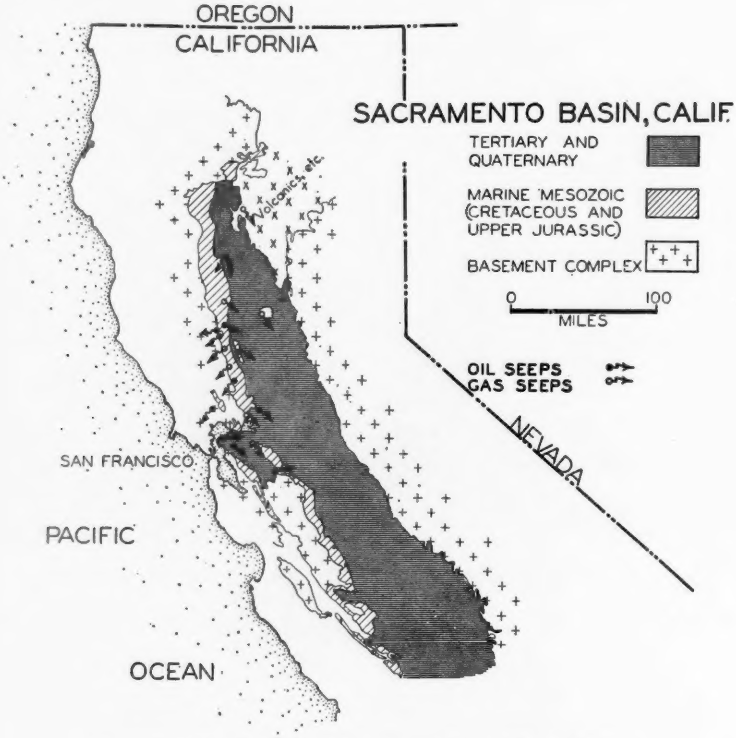

FIG. 7.—Map showing general features and location of oil and gas seeps in Sacramento Basin, California.

Although the area has been the object of considerable exploration, the occurrence of only gas fields has retarded interest of all except some of the major producing companies; however, the basin is undergoing active exploration at the present time with the drilling of mappable surface structures as well as seismograph anomalies.

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IMPERIAL VALLEY, CALIFORNIA

This area includes the Salton Sea southward to the Mexican border. Much of the surface is covered by alluvial and terrace material. A few anticlines are known. At the margins of the present basin, and within the basin itself, outcroppings of a thick section of non-marine beds are present. These beds which reach a thickness of 17,000 feet include marine beds of about 2,000 feet in thickness of Tertiary age. Their probable subsurface equivalent covers a widespread area, including the Mojave Desert and southern Nevada.

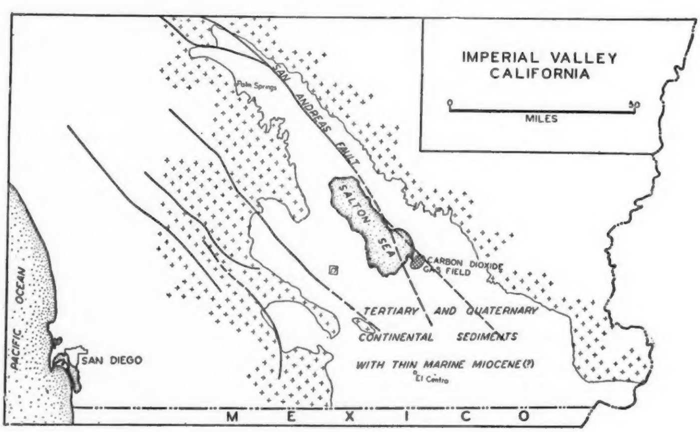

FIG. 8.—Map showing general features in vicinity of Imperial Valley, southern California.

No oil or gas seeps are known, but one well which was drilled on one of the best developed anticlines flows water with a small amount of gas.

About twenty wells have been drilled in the area. Two of them are probably the only ones which have tested the marine beds in any manner. The deepest of the two reached 4,115 feet.

Evidence of intense deformation may be seen in outcrops of truncated beds exposed on the valley floor. The area is crossed from northwest to southeast along its easterly margin by the southern prolongation of the San Andreas rift and other parallel faults. Seismic activity and recent geologic evidence of faulting is marked.

Near the south edge of the Salton Sea several shallow wells produce pure carbon dioxide gas. This occurrence is probably related to nearby volcanic plugs rather than structure. Many mud volcanoes are found in the vicinity.

No exploration by drilling is being carried on at present.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 25, NO. 8 (AUGUST, 1941), PP. 1469-1507, 27 FIGS.

POSSIBLE FUTURE OIL PROVINCES IN ROCKY MOUNTAIN REGION

ROCKY MOUNTAIN ASSOCIATION OF PETROLEUM GEOLOGISTS[1]
Denver, Colorado

INTRODUCTION

Since the discovery of the World's second oil field near Cañon City, Colorado, in 1862, oil or gas—or both—have been produced at about 176 localities in the Rocky Mountain states north of central New Mexico. About 58 per cent of the oil and gas fields are anticlines and domes whose producing areas are either not faulted or only slightly faulted at the surface, 26 per cent are faulted anticlines and domes and fault blocks, 14 per cent are monoclines and terraces, and 2 per cent are plunging anticlines and structural noses. The lowest surface elevation in a producing area is about 2,167 feet in the Bowdoin gas field, Montana, and the highest is 8,000 feet and more in the Wilson Creek, McCallum, and Price fields, Colorado.

The oldest orogeny clearly differentiated in the region is the late pre-Cambrian disturbance of the Grand Canyon and vicinity. The second orogenic disturbance, occurred mainly in the southern part of the region in the late Paleozoic, being represented in parts of Montana and Wyoming by broad warping, such as that along the present Sweetgrass arch, Montana. There was continual epeirogeny in the region during the Paleozoic and Mesozoic, and some rather local orogeny that occurred along the western border of the region during the late Jurassic continued intermittently into the late Cretaceous.

Although most of the observable folding in the Rocky Mountain region was caused by vertical and compressive stresses exerted generally from the west during the varied and prolonged pulsations of the late Mesozoic and early Tertiary Laramide revolution, some of the Laramide folds are posthumous after late Paleozoic uplifts—especially in Colorado and northern New Mexico.

The present dissected Rocky Mountains are largely the result of several post-Laramide epeirogenic movements—probably isostatic adjustments—in the Tertiary and Quaternary, separated by periods of erosion, the high altitudes of some ranges being largely caused by renewed movements along faults and by regional arching. Block faulting that began in the late Pliocene along the west border of the region

[1] Committee consists of C. E. Dobbin, United States Geological Survey, chairman; A. E. Brainerd, Continental Oil Company; R. L. Heaton, United States Bureau of Reclamation; H. W. Oborne, consulting geologist; H. A. Stewart, The Texas Company; W. O. Thompson, University of Colorado; and F. M. Van Tuyl, Colorado School of Mines.

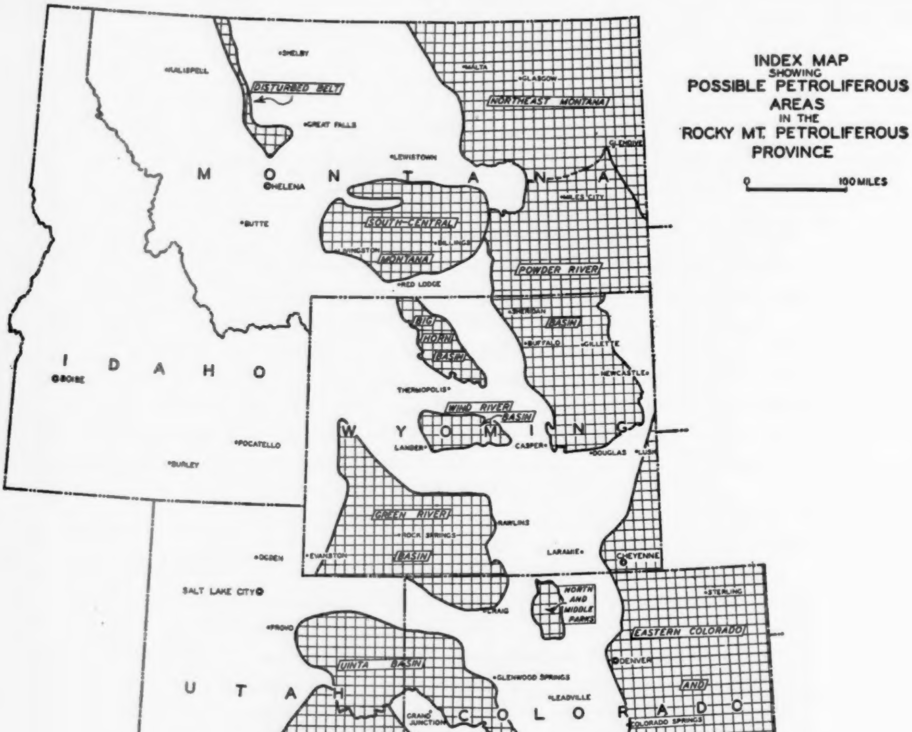
INDEX MAP
SHOWING
POSSIBLE PETROLIFEROUS
AREAS
IN THE
ROCKY MT. PETROLIFEROUS
PROVINCE
0
100 MILES
MONTANA
IDAHO
WYOMING
UTAH
COLORADO
ARIZONA
NEW MEXICO
DISTURBED BELT
NORTHEAST MONTANA
SOUTH-CENTRAL
MONTANA
POWDER RIVER
BASIN
BIG
HORN
BASIN
WIND RIVER
BASIN
GREEN RIVER
BASIN
NORTH
AND
MIDDLE
PARKS
EASTERN COLORADO
AND
VICINITY
UINTA BASIN
COLORADO RIVER
SALT
BASIN
BLACK MESA
BASIN
SAN JUAN
BASIN
SHELBY
KALISPELL
MALTA
GLASGOW
GREAT FALLS
GLENDIVE
LEWISTOWN
HELENA
MILES CITY
BUTTE
BILLINGS
LIVINGSTON
RED LODGE
SHERIDAN
BUFFALO
GILLETTE
NEWCASTLE
BOISE
THERMOPOLIS
LANDER
CASPER
DOUGLAS
LUSK
POCATELLO
BURLEY
RAWLINS
ROCK SPRINGS
EVANSTON
OGDEN
LARAMIE
CHEYENNE
SALT LAKE CITY
STERLING
CRAIG
PROVO
DENVER
GLENWOOD SPRINGS
LEADVILLE
GRAND JUNCTION
COLORADO SPRINGS
MOAB
PUEBLO
LAMAR
CEDAR CITY
TRINIDAD
DURANGO
RATON
SANTA FE
LAS VEGAS
TUCUMCARI
FLAGSTAFF
HOLBROOK
ALBUQUERQUE
PHOENIX
ROSWELL
TUCSON
LORDSBURG
EL PASO

FIG. 1

has continued intermittently to the present. Locally, the relative uplift between a major uplift and its contiguous structural basin is as much as 30,000 feet. Except along the west border of the region, there is very little evidence of structural growth during the Mesozoic prior to Laramide orogeny.

Oil seeps are not shown on some of the maps depicting many oil and gas fields, for example, those of the Big Horn, Powder River, and San Juan basins.

Because time would not permit serious study of the total volume of strata present in the various areas, it is probable that the figures given are somewhat excessive—at least for certain areas.

The wells shown in the possible petroliferous areas on the maps are all the important ones therein. The letters beside the wells indicate the age of the lowest formation drilled, according to the following explanation.

E, Eocene	*P*, Permian	*O*, Ordovician
C, Cretaceous	*Pn*, Pennsylvanian	*€*, Cambrian
J, Jurassic	*M*, Mississippian	*P€*, Pre-Cambrian
T, Triassic	*D*, Devonian	

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DISTURBED BELT

MONTANA

The narrow northern sector of the Disturbed Belt in Montana is a structural transition zone embracing 1,900 square miles east of the Rocky Mountain Front zone of major thrusting, west of the gently folded Sweetgrass arch, and south of the international boundary to Missouri River. The average total thickness of strata is 2 miles and the total volume is 3,800 cubic miles. The belt is featured by closely compressed, elongate anticlines, some of which are overturned eastward and some of which are underlain by low-angle thrust faults of considerable stratigraphic displacement. Local thrust faults that merge into asymmetric folds and then appear again along the strike predominate;

most dips are steep and erratic; and deep tests drilled on the sharp anticlines ordinarily pass through at least one low-angle thrust fault and end in strata of the same age as those at the surface or younger; or they find a considerable horizontal axial displacement with depth.

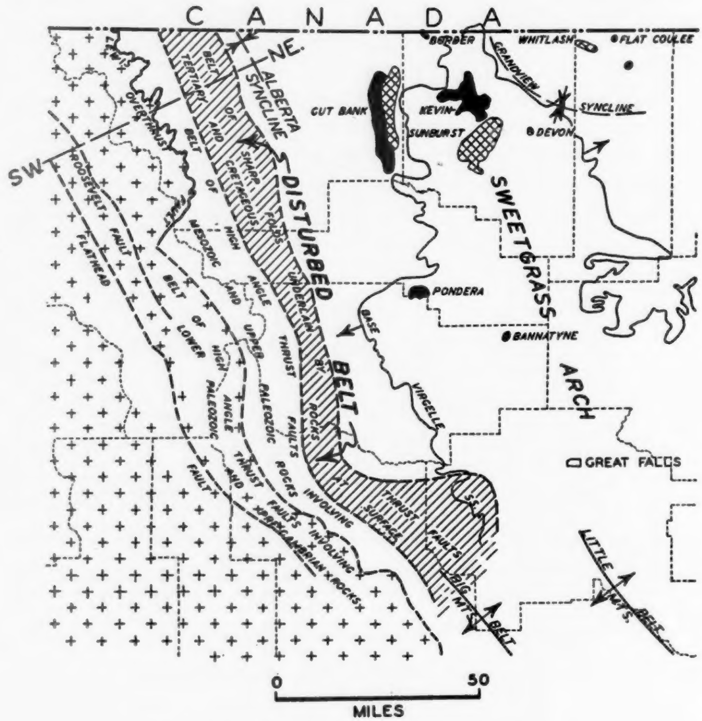

FIG. 2.—Map showing Disturbed Belt in Montana.
Area discussed is cross-hatched.

Excluding the late Tertiary and Pleistocene cover, 12 post-Belt (pre-Cambrian) formations are present, ranging in age from Cambrian to Tertiary (?) and having a total thickness of about 10,000 feet. Jurassic and older beds (50 per cent) down to the Cambrian, inclusive, are predominantly marine, and younger beds (50 per cent) are mostly non-marine. About 28 per cent of the total section is shale, 27 per cent limestone, and 45 per cent sandstone. Except for the Cambrian, all formations have been drilled somewhere in the belt, but few have been penetrated in entirety and no single test has drilled a full, regular sequence of more than three.

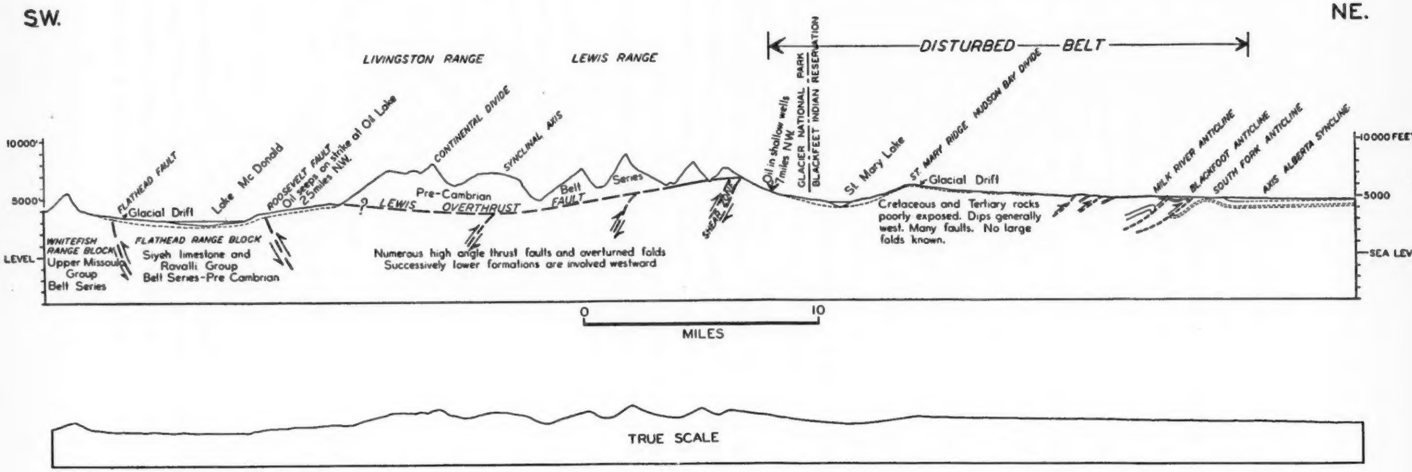

FIG. 3.—Generalized structure section across Disturbed Belt in Montana. See Figure 2 for location of section.

Regional unconformities separate Devonian strata from Cambrian, lower Mississippian from Devonian, Upper Jurassic from lower Mississippian, and Lower Cretaceous from Upper Jurassic. From the standpoint of future oil production, the unconformity between the Ellis formation (Upper Jurassic) and the Madison limestone (lower Mississippian) is potentially the most important, because it separates an acknowledged source of oil from a recognized reservoir in the eroded and weathered top of the Madison. Next in significance is the unconformity between the basal sandstone zone of the Kootenai formation (Lower Cretaceous) and the top of the Ellis.

Although no encouraging showings of oil and gas have been found in wells drilled in the Disturbed Belt in Montana, the complex Turner Valley field, Alberta, yields oil and gas in it from the Madison limestone. Source rocks in the belt are about 50 feet of bituminous shale in the lower part of the Colorado shale (Upper Cretaceous), probably the greater part of the Ellis formation, and, if present, certain parts of the Jefferson limestone (Devonian).

That there are many anticlines—some large—in the Disturbed Belt is known; in fact, 29 tests have been drilled in the belt and 10 districts prospected. However, 20 of the tests were not drilled deep enough. In only two wells was the Madison limestone reached in wells that started in the Colorado shale, and it has never been reached in wells starting in post-Colorado beds.

The failure to find commercial amounts of oil and gas in the Disturbed Belt is largely due to a lack of understanding and consequent misinterpretation of the geologic structure. As metamorphism is rather strong near the Rocky Mountain Front, the ideal conditions sought should be anticlinal structure in the Madison limestone outside the zone of metamorphism and at economical drilling depth. The abundance of anticlines in this relatively large area suggests that oil will eventually be discovered in it.

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NORTHEAST MONTANA

The consolidated surface beds in northeast Montana are mostly Upper Cretaceous and Eocene continental deposits that generally dip gently eastward into the Williston structural basin of western North Dakota and into the north end of the Powder River structural basin

of southeast Montana and northeast Wyoming. The area embraces 29,300 square miles, the average total thickness of the strata is 1.7 miles, and the total volume is about 50,000 cubic miles.

There are two gas fields in the area: Bowdoin and Cedar Creek (Baker-Glendive), both producing from Upper Cretaceous sands at depths of 740–1,000 feet and 800–1,500 feet, respectively. In the Cedar Creek anticline, strong showings of black oil were found in Mississippian and Devonian (?) beds at the respective depths of 6,747 and 8,130 feet; and at Bowdoin, one dry hole was completed at a total depth of 3,180 feet in Pennsylvanian (?) beds. The remaining few dry holes in the area bottomed in Cretaceous beds.

On the Nesson anticline, Williams County, North Dakota, 48 miles east of the Montana-North Dakota boundary, a well beginning in Tertiary coal-bearing beds drilled 10,281 feet of continental, brackish-water and marine beds, and stopped in Ordovician (?) strata. As much of the pre-Cretaceous section drilled in this well differs greatly from that exposed in far mountainous uplifts and from that drilled in distant wells and because there are known regional convergences and divergences of strata, one can not at present be even moderately positive as to the character, thickness, and relations of pre-Cretaceous beds in all northeast Montana. There is, however, a regional unconformity at the base of Jurassic beds, which in a northerly and westerly direction rest on progressively older beds ranging in age from Triassic to lower Mississippian, and probably another at the base of the Devonian.

Development has been very slow in much of northeastern Montana, largely because of the low folding in exposed beds and relatively deep drilling to promising objectives.

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SOUTH-CENTRAL MONTANA

The south-central Montana area covers 11,100 square miles. As a whole, it is a rather variable and complex synclinal area featured by lofty volcanic mountains, peculiar fault zones, variable structure, and great lithologic changes. Three to 11,000 feet of strata are present in the area, ranging in age from Cambrian to Tertiary. The total volume of strata present is about 22,000 cubic miles. Ordovician strata that

crop out near Cody, Wyoming, seemingly feather out a short distance north of the Montana-Wyoming boundary; Devonian strata that are apparently absent near Cody develop along the south border of the area and thicken northward to the Big Snowy Mountains; a relatively thick section of upper Mississippian beds pinches out not far south-

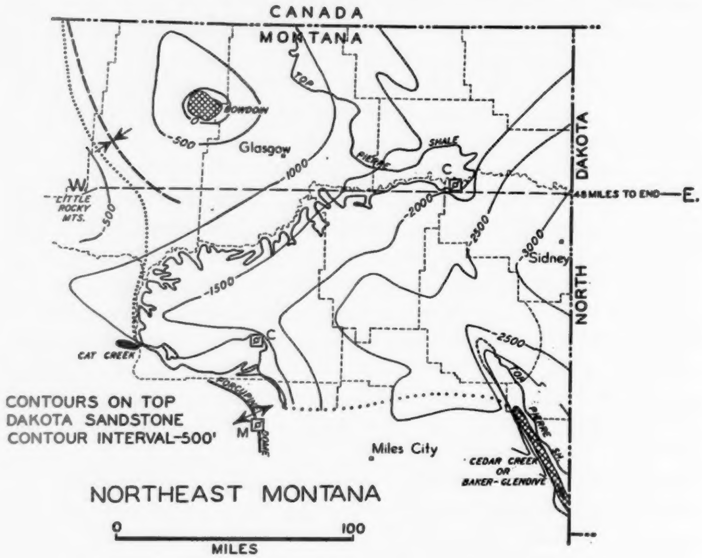

FIG. 4.—Map showing general features of northeastern Montana. Area described is within dotted line.

ward from the Big Snowy Mountains; relatively thin Permian and Pennsylvanian strata present near Cody feather out northward; Triassic and Permian redbeds that are relatively thick along the south border of the area pinch out northward; Lower Cretaceous beds thicken and assume a more continental aspect northward; and in the west-central part late Upper Cretaceous and Eocene strata are represented by andesitic beds.

Within the area oil is produced from Cretaceous beds in the relatively small Big Lake and Mosser fields and small amounts of gas are produced in the Hardin field. Oil is produced from Cretaceous beds in the Dry Creek field, along the south rim of the area, and small amounts of black oil come from Mississippian beds in the Devils Basin field along the north border. The Soap Creek field on the southeast produces some oil from Cretaceous, Pennsylvanian, and Mississippian beds.

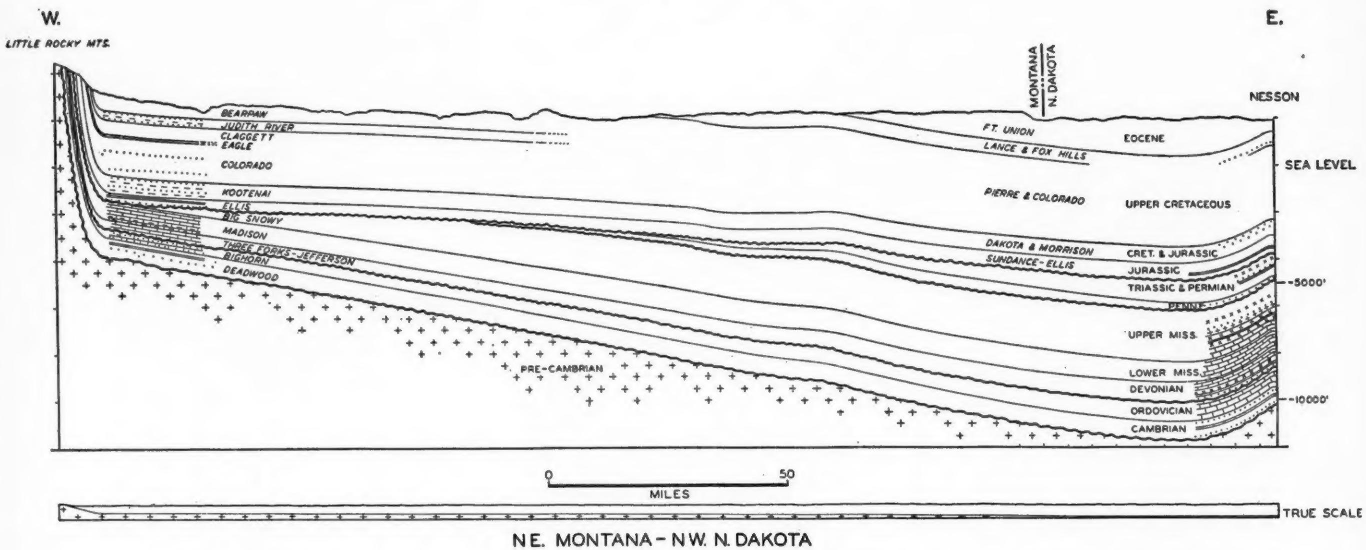

FIG. 5.—Generalized section across northeastern Montana into northwestern North Dakota. Line of section is shown in Figure 4.

Development has not proceeded further in south-central Montana because almost all surface anticlines in and bordering the area have been drilled and found unproductive. In addition, parts of the area are occupied by thick Tertiary formations, making the drilling depths to promising objectives rather great.

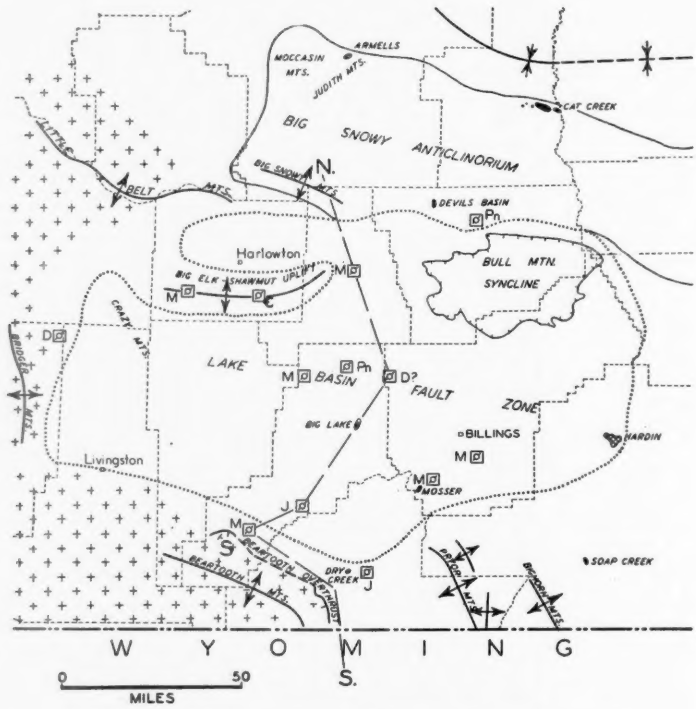

FIG. 6.—Map showing south-central Montana area. Area discussed is within dotted line.

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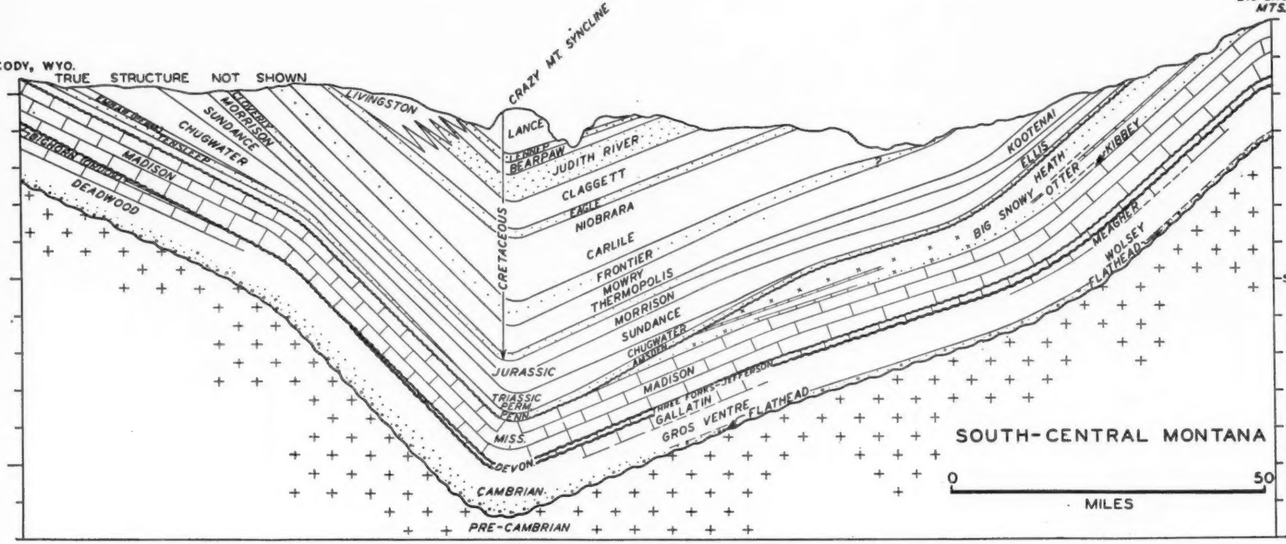

FIG. 7.—Generalized structure section across south-central Montana. See Figure 6 for location of section.

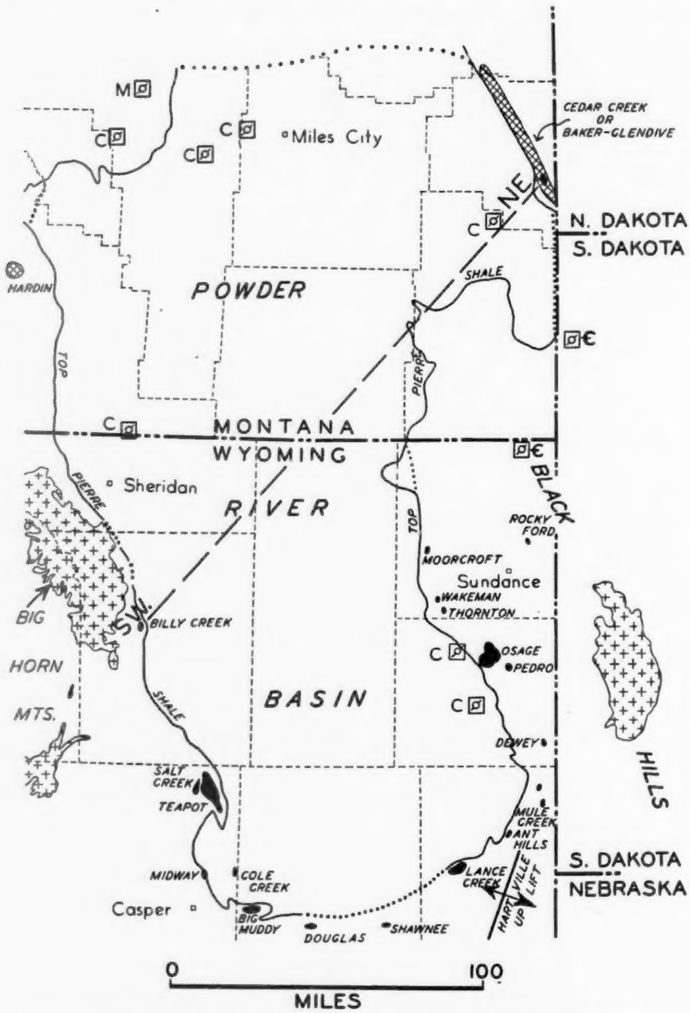

FIG. 8.—Map showing Powder River Basin, Montana and Wyoming. Area discussed is within dotted line and outcrop of top of Pierre shale.

KNAPPEN, R. S., AND MOULTON, G. F., "Geology and Mineral Resources of Parts of Carbon, Big Horn, Yellowstone, and Stillwater Counties, Montana," *ibid.*, *Bull. 822* (1930), pp. 1–70.

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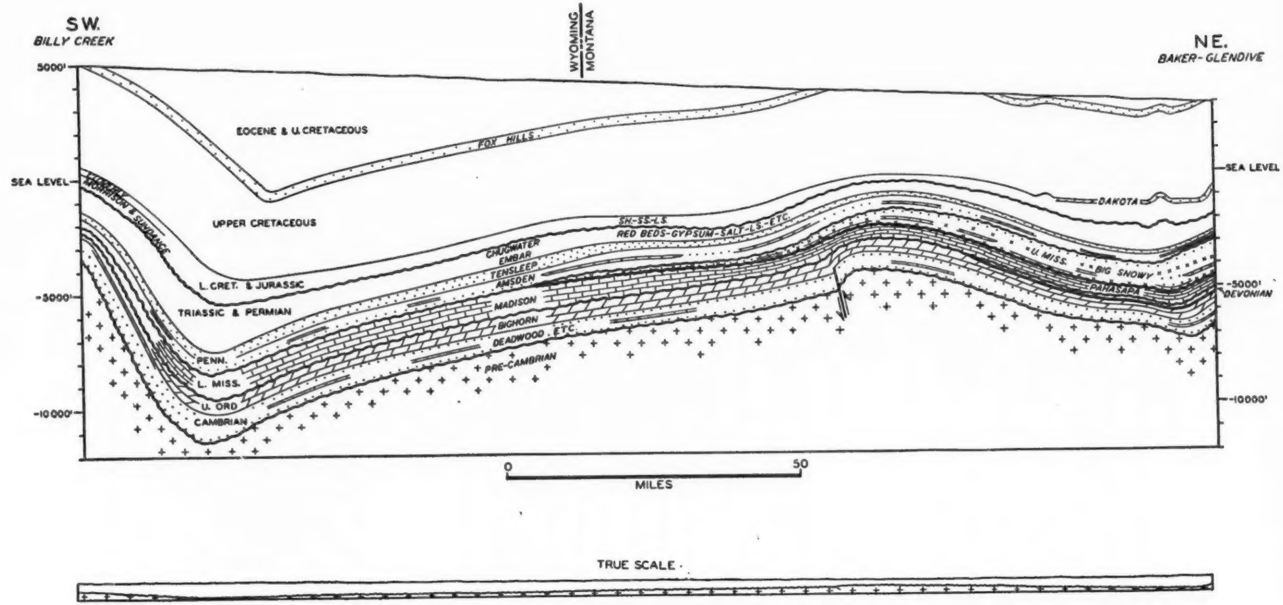

FIG. 9.—Generalized structure section across Powder River Basin in northeastern Wyoming and southeastern Montana. See Figure 8 for line of section.

Powder River Basin

MONTANA AND WYOMING

The Powder River Basin area covers 32,200 square miles in southeast Montana and northeast Wyoming, being part of a major structural basin lying between the Black Hills and the Big Horn Mountains. Outcrops on the rims of the basin indicate that approximately 16,000 feet of strata, ranging in age from Upper Cambrian to Eocene, are present in the deepest part of the basin and that the total volume present is about 96,600 cubic miles. The exposed rocks—comprising about 32 per cent of the total sedimentary section—are late Upper Cretaceous and Eocene fresh-water strata, whereas almost all older beds are marine. The oldest formation drilled in the area is of Upper Jurassic age.

Oil seeps have been known on all sides of the Powder River Basin in Wyoming since pioneer days. As shown by the map, there are many oil and gas fields rimming parts of the basin that either yield or have yielded oil from beds ranging in age from Mississippian to Oligocene.

The existence of so many oil and gas fields on the rim of the Powder River Basin indicates the presence of source and reservoir beds within the basin. However, as no wells have been drilled below the Upper Jurassic in the central part of the basin, no detailed geological data are available on the character and thickness of Paleozoic beds there, and particularly on the exact nature of the postulated wedging-out of upper Mississippian and Devonian beds southwest of the Cedar Creek (Baker-Glendive) field, Montana.

The Powder River Basin has not been actively prospected for oil and gas heretofore, for (1) there is very little local deformation, and (2) the depths to promising objectives are thought to be relatively excessive.

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Big Horn Basin

WYOMING

The Big Horn Basin area covers 3,000 square miles in northwest Wyoming, being a major structural basin bordered by a series of anticlines which are satellite to contiguous major uplifts. The exposed beds are largely Wasatch (Eocene) and are unconformable on older beds—at least on the rims of the basin. Outcrops in and near the foot-

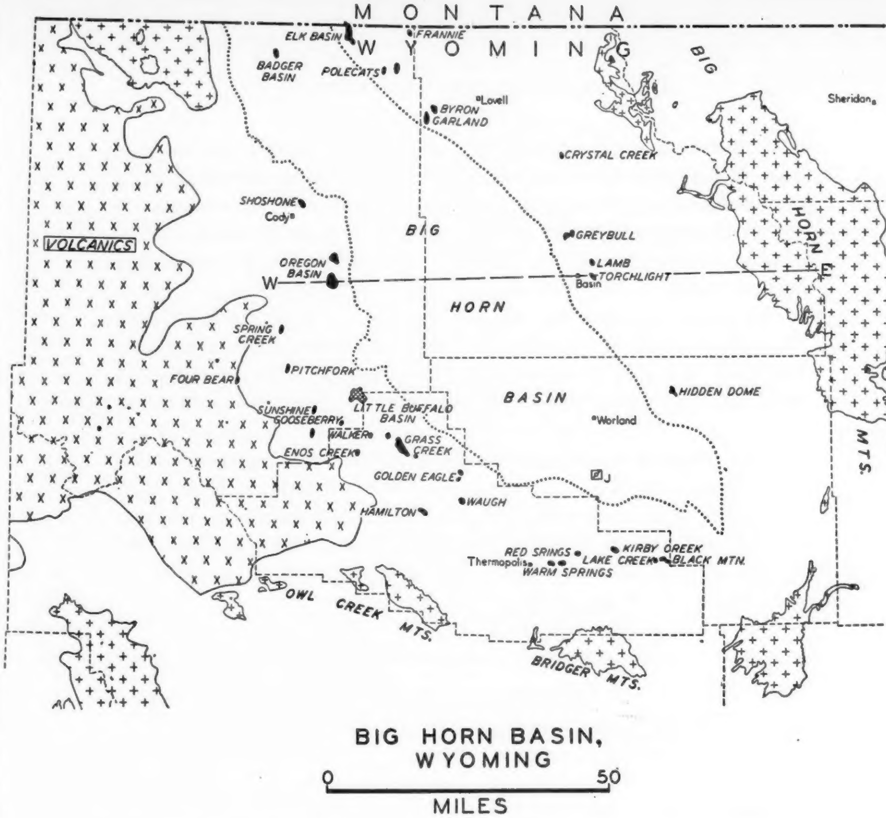

FIG. 10.—Map showing general features in vicinity of Big Horn Basin, northern Wyoming. Area described is within dotted line.

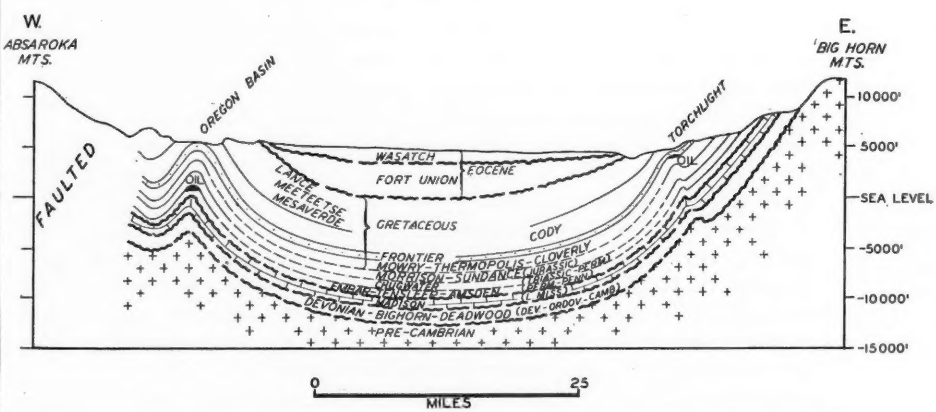

FIG. 11.—Generalized structure section across Big Horn Basin, Wyoming. Line of section is shown in Figure 10.

hills indicate that approximately 17,000 feet of strata, ranging in age from Middle Cambrian to Eocene are present in the deepest part of the basin and that the total volume present is about 9,600 cubic miles. A well in the Badger Basin field started in Eocene beds next below the Wasatch and at a total depth of 10,121 feet bottomed in high Upper Jurassic beds.

As shown by the map, many oil and gas fields surround the Big Horn Basin area. The producing formations range in age from Mississippian to Upper Cretaceous, and the traps are rather sharp, elongated anticlines, some being severely faulted at the surface and others not.

The existence of so many oil and gas fields on the rim of the Big Horn Basin area indicates the presence of source and reservoir beds within the area. However, the absence of pronounced local deformation in the overlapping Tertiary strata covering most of the area and the expected great depths to promising objectives have retarded development.

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Wind River Basin

WYOMING

The Wind River Basin area is a structural basin embracing 2,500 square miles in west-central Wyoming, being bordered on several sides by major uplifts. The surface rocks are largely overlapping Eocene beds that effectively prevent the determination of the character and attitude of older beds by ordinary geologic methods. Strata ranging in age from Cambrian to Eocene crop out in the foothills and presumably are present beneath the area; in fact, it is believed that close to 20,000 feet of strata lie in its deepest part. The total volume of strata present is about 6,250 cubic miles. The chief pre-Wind River (Eocene) unconformities present are erosional, occurring at the base of the Cambrian and of the Mississippian.

Bordering the Wind River Basin area on three sides are 14 oil and gas fields, some of which produce low-gravity black oil from Pennsylvanian, Permian, and Triassic beds and others that yield higher-grav-

ity green oil from Upper Cretaceous beds. At the surface, eleven of these producing fields are relatively sharp, unfaulted anticlines, and three are rather strongly faulted. Just southeast of the area a number of fields yield oil and gas from all the zones—except one—that produce in the aforementioned 14 fields. In addition, oil seeps occur in rocks ranging in age from Cambrian to Oligocene at numerous localities bordering the area.

As so many oil and gas fields border the Wind River Basin area, there is justification for believing that some fields occur in it. However, prospecting has been greatly restricted, for (1) no prominent anticlines have been found in the overlapping Eocene beds, and (2) the depth to promising lower objectives is thought to be relatively excessive.

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Green River Basin

WYOMING AND COLORADO

The Green River Basin area covers 18,000 square miles in southwest Wyoming and northwest Colorado. It is bordered on the west by a north-south-trending belt of major thrust faults, on the north and east by the Wind River Mountains, Rawlins, and Sierra Madre uplifts, and on the south by the Uinta Mountains uplift and its southeast extensions. In general, the area consists of two major structural basins separated near the middle by the north-trending Rock Springs anticline.

In the deepest parts of the area, interfingering middle and upper(?) Eocene beds crop out, and elsewhere, except in the Rock Springs anticline, overlapping lower Eocene beds are usually at the surface. That the continental Tertiary section is very thick in the area is indicated by the record of a deep well in the northwest part, which, at a total depth of 10,000 feet, probably bottomed in lowest Eocene beds. Further information on the depth to lower zones is afforded by one well on the Rock Springs uplift, which started in Upper Cretaceous marine

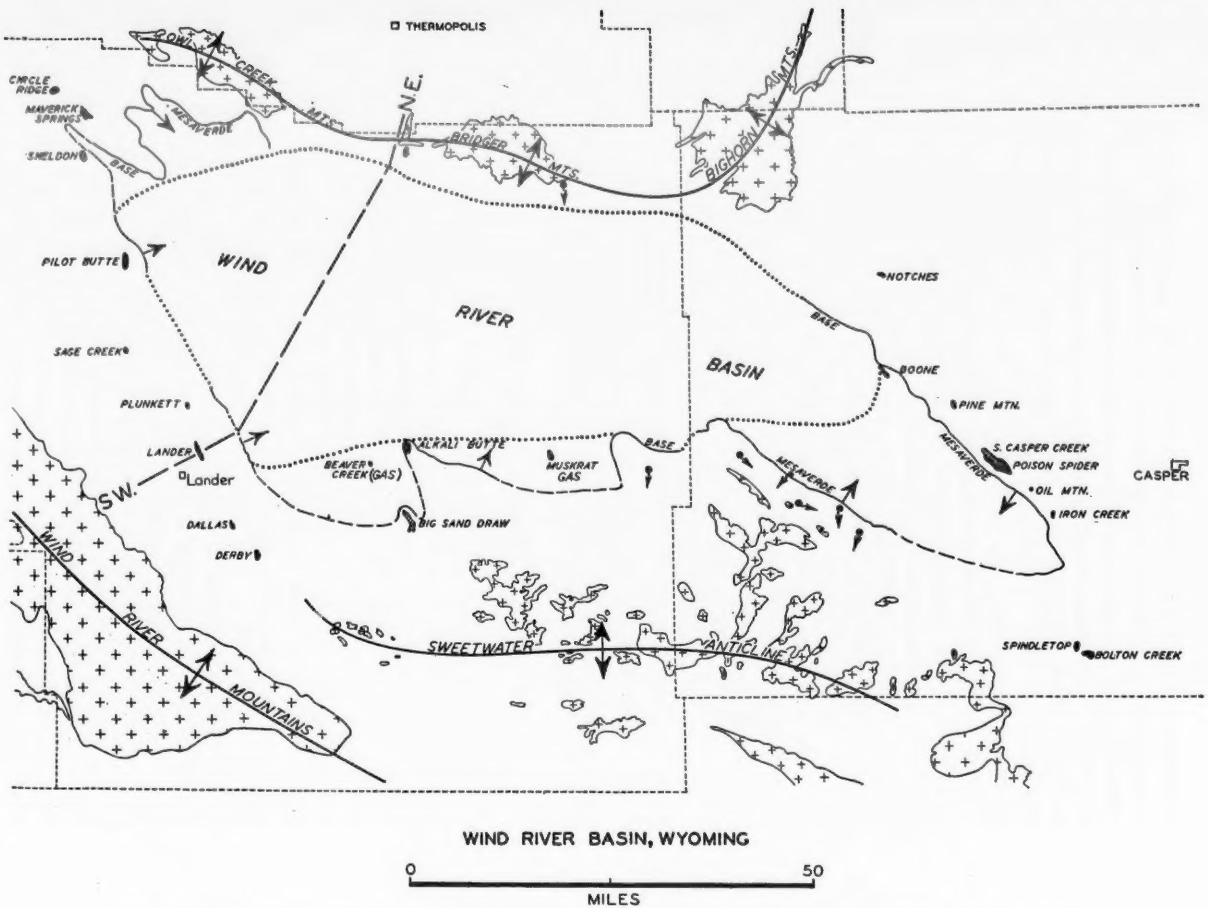

FIG. 12.—Map showing general features of Wind River Basin region, Wyoming. Area discussed is within dotted line.

MILES

FIG. 12.—Map showing general features of Wind River Basin region, Wyoming. Area discussed is within dotted line.

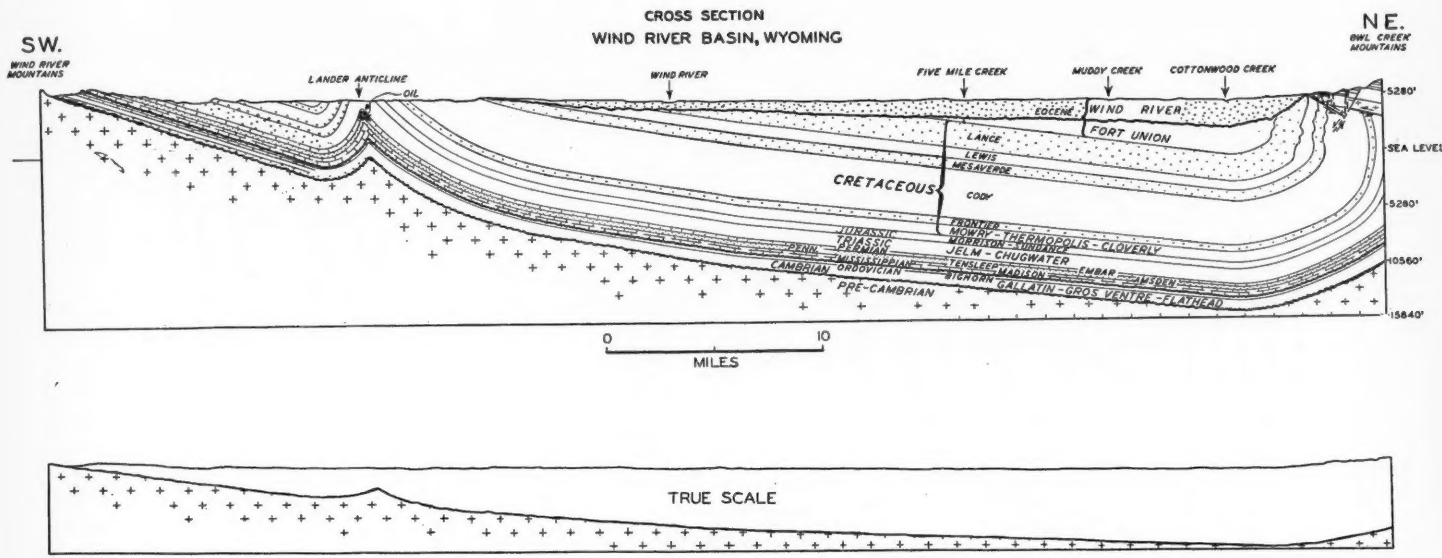

FIG. 13.—Generalized structure section across Wind River Basin, Wyoming. See Figure 12 for line of section.

shale and at a total depth of 6,302 feet bottomed in Pennsylvanian sandstone. It is thought, therefore, that 25,000–30,000 feet of strata are present down to the base of the Mississippian in deeper parts of the area and that there is a pronounced thickening westward and northwestward of many formations. In addition, it is probable that

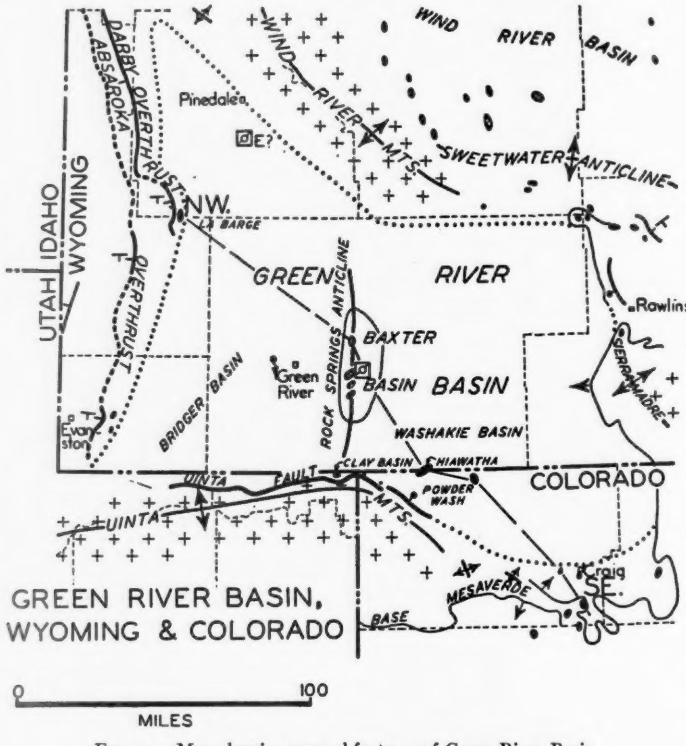

FIG. 14.—Map showing general features of Green River Basin (within dotted line), Wyoming and Colorado.

at least 12,000 feet of pre-Mississippian Paleozoic strata are present in parts of the area.

A structural unconformity occurs at the base of the Wasatch formation (Eocene) and erosional unconformities occur at the bases of three other Eocene formations. Another prominent unconformity occurs at the base of the Pennsylvanian. Although there are a number of oil seeps just outside the area, there are very few in it.

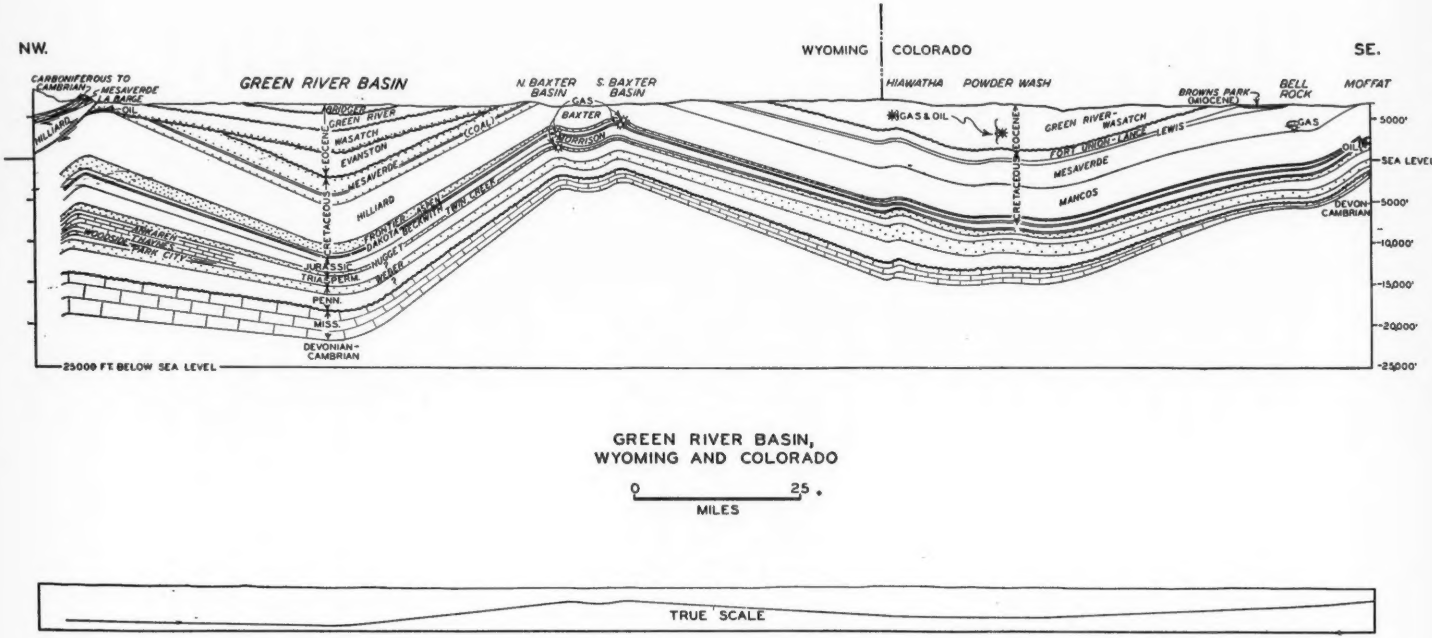

FIG. 15.—Generalized structure section across Green River Basin, Wyoming and Colorado. For line of section, see Figure 14.

In the Rock Springs uplift gas is produced from Upper Cretaceous and Upper Jurassic beds, and at Hiawatha and Powder Wash domes gas and oil are produced from lenticular lower Eocene beds. Along the southeast border of the area, in northwest Colorado, oil is produced from Upper Cretaceous and Upper Jurassic beds in several fields; just east of the major overthrusts at the west edge of the area, oil is produced from Upper Cretaceous and lower Eocene beds; and at the northeast edge of the area beds ranging in age from Pennsylvanian to Upper Cretaceous yield relatively large amounts of oil.

The greater part of the Green River Basin beyond present producing fields has been prospected very little for oil and gas, for there is very little known folding in the outcropping Tertiary beds and because the depths to pre-Eocene beds is known to be great. There is reason to believe that more oil will be found in lenticular Tertiary sands, as at Powder Wash and Hiawatha domes.

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NORTH AND MIDDLE PARKS

COLORADO

The North and Middle Parks area embraces 1,500 square miles lying between mountainous uplifts in north-central Colorado. In general, the area is a structural basin, though marginal anticlines are known and incomplete exposures prove the presence of faulting beneath overlapping Tertiary and Quaternary deposits. About 14,000 feet of strata lie above pre-Cambrian granite and schist on the margins of the area, 43 per cent being fresh-water Tertiary beds, 45 per cent largely Cretaceous marine shale and sandstone, 2 per cent fresh-water Jurassic shale and sandstone, and 10 per cent Triassic redbeds. A thin marine limestone of Permian or Pennsylvanian age crops out in the northeast part. It is possible, however, that older Paleozoic beds are present at depth in the central part of the area.

Major unconformities occur at the base of the Miocene, Eocene, Triassic, and Permo-Pennsylvanian, and probably at the top and bottom of the Jurassic. Evidence of folding prior to the deposition of Eocene beds is rather strong.

Oil seepages are present on the west side of the area, and the Upper Cretaceous Dakota sandstone yields some 50° gravity oil and large volumes of carbon dioxide gas in the sharp offsetting McCallum anticlines.

North and Middle Parks have not been extensively prospected for oil and gas because (1) Tertiary and Quaternary beds overlap large portions of the area, (2) large volumes of carbon dioxide gas occur with the oil in the McCallum fields and (3) operating and marketing conditions are rather unfavorable.

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EASTERN COLORADO AND VICINITY

The area designated "Eastern Colorado and Vicinity," embraces 68,500 square miles at the west edge of the Great Plains. In northeast New Mexico and most of southeast Colorado the beds dip rather gently away from the northeast-trending Sierra Grande-Las Animas arch and elsewhere they dip gently into the north-south-trending Denver Basin. Paleozoic, Mesozoic, and Tertiary beds of variable thickness and character underlie the area, the Tertiary strata being of fresh-water origin and the older beds being partly marine and partly continental; in fact, a change from a westward continental and marine facies to an eastward marine facies features an important part of the Paleozoic section.

In addition to observable folding caused by the Laramide revolution, certain areas were subjected to late Paleozoic orogeny that had a great bearing on the distribution, thickness, and character of pre-Permian beds over rather broad areas. Although Pennsylvanian and older Paleozoic beds are not present on the higher portions of the buried ridges of pre-Cambrian rocks along the Sierra Grande-Las Animas arch—and possibly in the Apishapa uplift—they appear with rapid changes in age and thickness on certain flanks. No Silurian or Devonian beds are present in the area, and in northeast New Mexico Pennsylvanian strata lie on pre-Cambrian granite and schist.

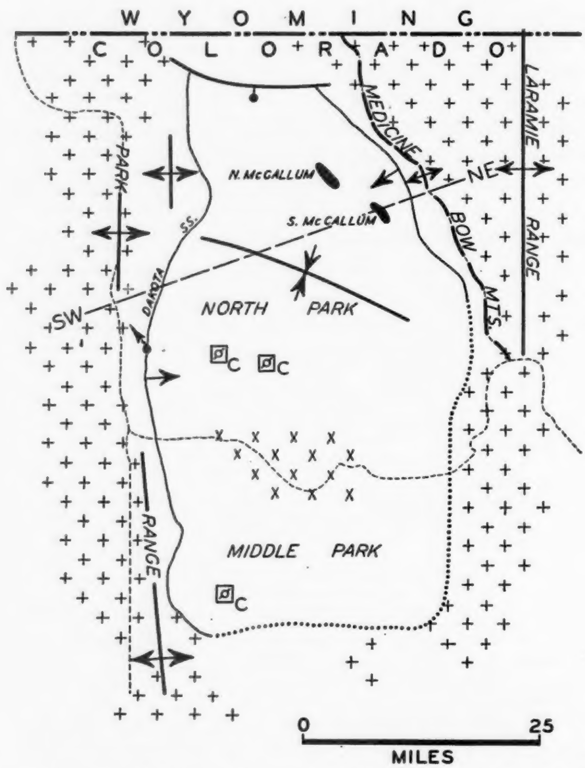

FIG. 16.—Map showing general features in North and Middle Parks, Colorado. Area described is within dotted line and line of Dakota sand outcrop.

Within the designated area in Colorado oil is produced from Upper Cretaceous beds in the Greasewood and Florence-Cañon City fields, gas comes from Upper Cretaceous beds in the small Garcia and Wray fields and rich helium gas comes from Jurassic (?) beds at Model dome. In the Bueyeros field, New Mexico, several low domes yield rich carbon dioxide gas from Triassic beds. In addition, several small fields produce oil from Upper Cretaceous beds just west of the area in northern Colorado. However, widespread deep drilling in the area has failed to develop pre-Cretaceous oil production.

It is possible that oil will be found in Cretaceous beds in low domes bordering the deeper parts of the Denver Basin, in stratigraphic traps where certain continental and marine Paleozoic beds on the west

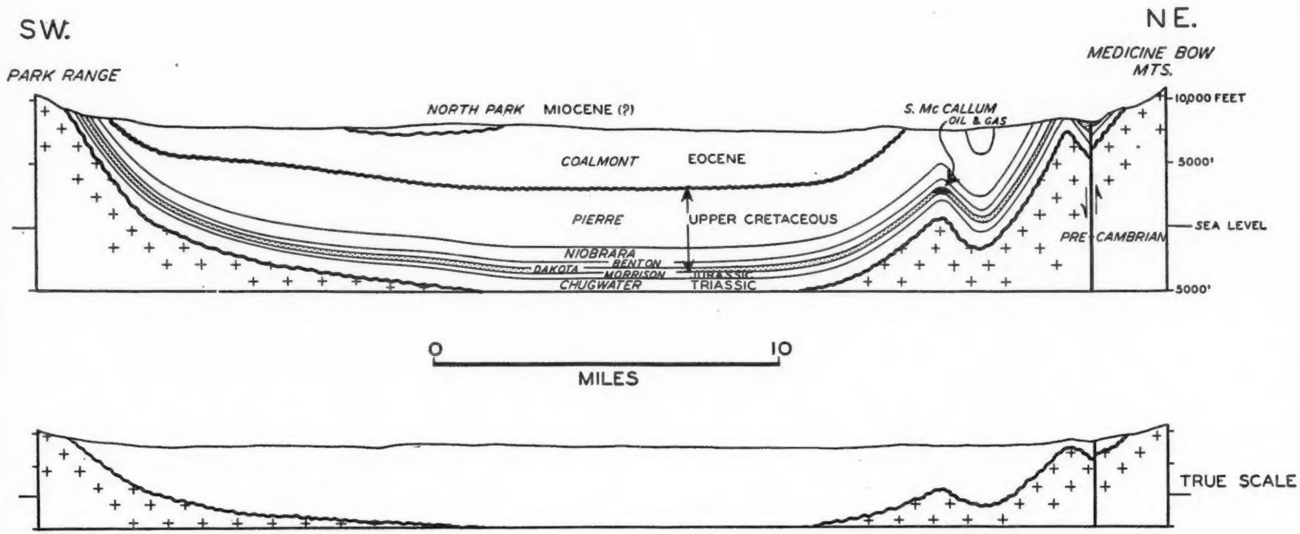

FIG. 17.—Structure section across North Park, Colorado. For location of section, see Figure 16.

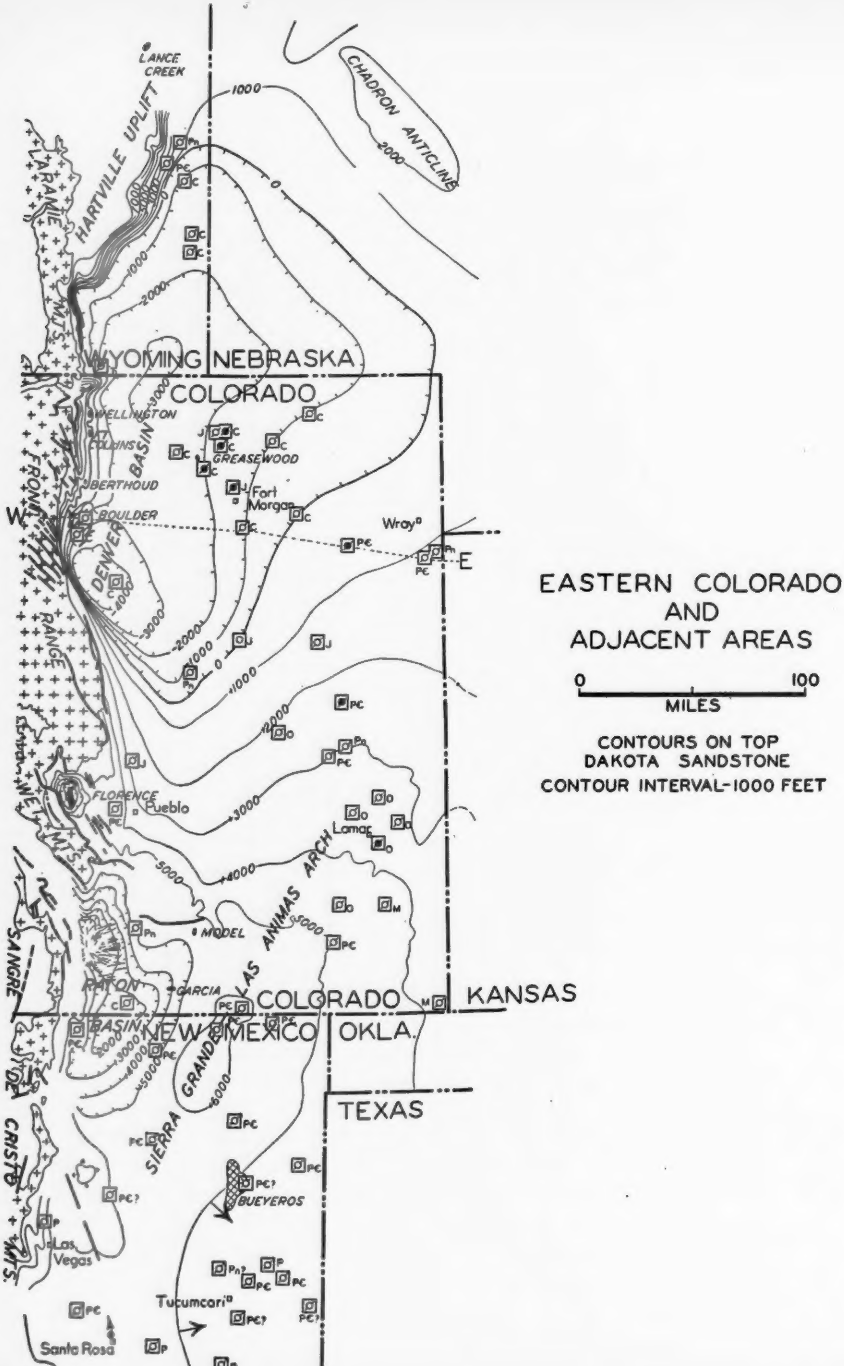

FIG. 18.—Map showing general features of eastern Colorado and adjacent parts of New Mexico, Wyoming, and Nebraska.

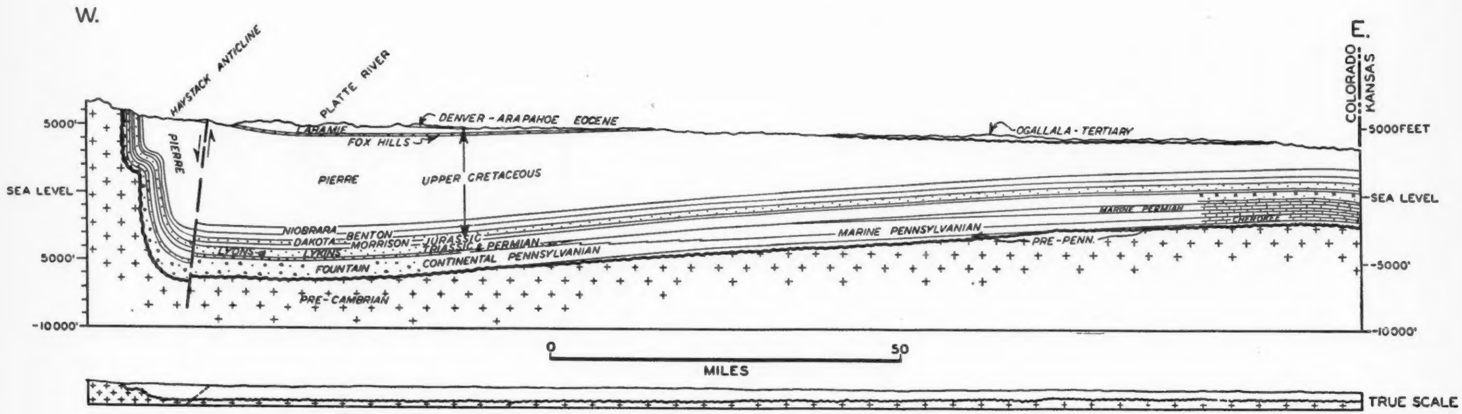

FIG. 19.—Generalized structure section across Denver Basin, Colorado. For line of section, see Figure 18.

merge into marine equivalents eastward, where Paleozoic beds thicken and change in character on the flanks of buried ridges of pre-Cambrian rocks, where Cretaceous marine shales are fractured, and in undiscovered Paleozoic upfolds.

Development is now retarded in the area because rather widespread recent deep drilling based largely on seismograph work has failed to develop substantial production, and, in some critical cases at least, has failed to reveal a promising sedimentary section.

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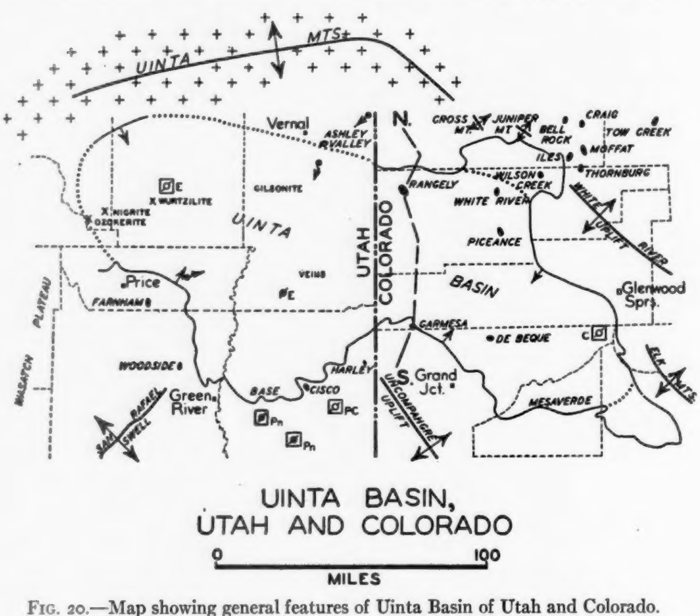

FIG. 20.—Map showing general features of Uinta Basin of Utah and Colorado. Area described is within line of base of Mesaverde formation and dotted line.

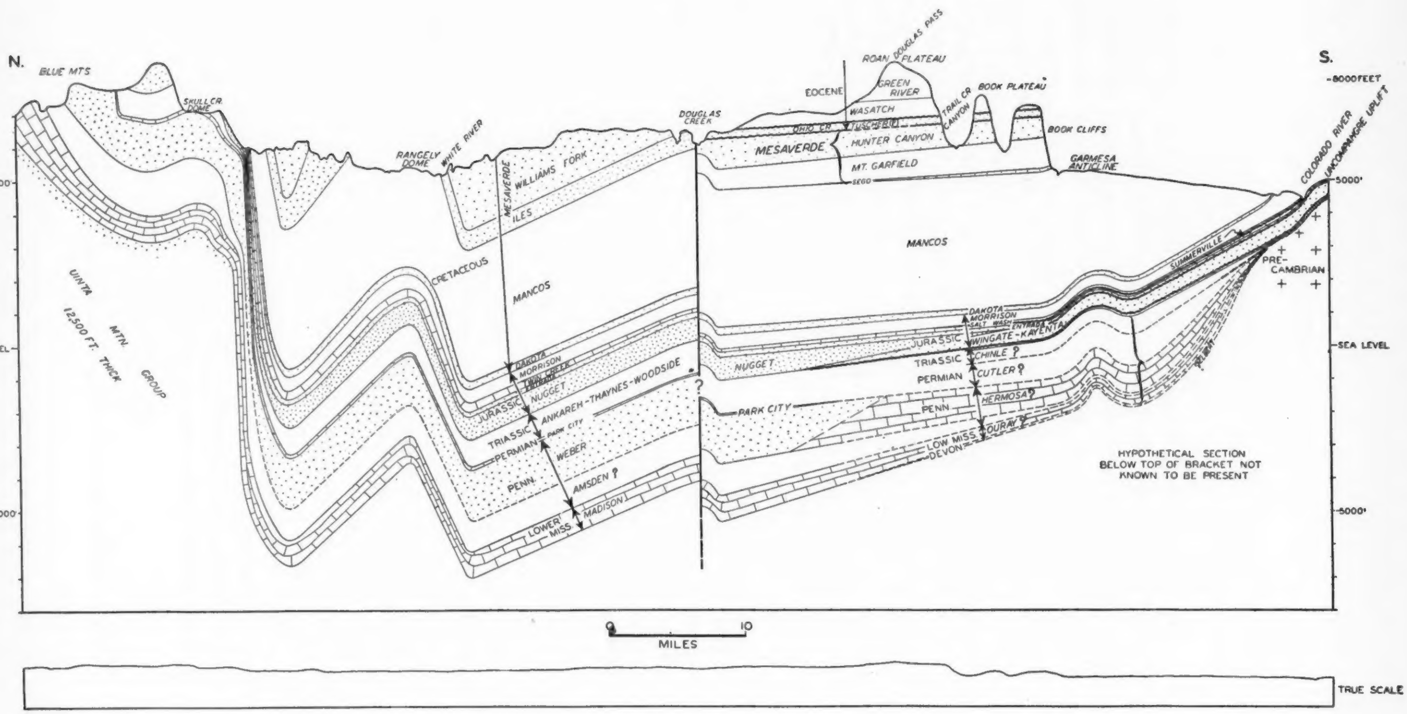

FIG. 21.—Generalized structure section across Uinta Basin, Colorado. See Figure 20 for line of section.

Uinta Basin

UTAH AND COLORADO

The Uinta Basin area covers 13,600 square miles in west-central Colorado and east-central Utah, being largely a major structural basin lying between major uplifts and abutting against the faulted Wasatch mountains on the west. It is believed that at least 20,000 feet of strata are present in the deeper parts of the area, ranging in age from Cambrian to Miocene. The deepest well in the area that drilled a normal section began in Upper Cretaceous marine shale and stopped in Pennsylvanian sandstone at a total depth of 7,173 feet. The records of this well and of other wells in and just outside the area indicate that the Paleozoic section is largely thick continental sandstone and shale, marine limestone, and some local evaporites; that Mesozoic beds are largely continental sandstone and shale at the top and bottom with intervening marine shale, and that the Tertiary section is continental sandstone and shale.

The unconformity observed at several places just outside the area that is of particular interest to oil-seekers in the area is that between the pre-Cambrian and overlapping beds—ordinarily Triassic or Jurassic—for wedges of intervening beds appear in short distances away from points of exposed overlap. Locally, however, older beds rest on the pre-Cambrian just outside the area, and within it most Tertiary formations have erosional unconformities at their bases.

Within the Uinta Basin area, small amounts of oil occur in Cretaceous beds at Rangely and DeBeque (probably Eocene, too) and some is present in Pennsylvanian beds in the former field. Gas occurs in Eocene beds at Piceance and White River domes, and just outside the area it is present in Permian, Jurassic, and Upper Cretaceous beds in several fields, that at Farnham and Garmesa being rich in carbon dioxide and that at Woodside and Harley being rich in helium. Fields just northeast of the area yield oil from Jurassic and Cretaceous beds, and in many parts of the area are deposits of oil shale, oil saturated sands, and numerous exposed veins of solid hydrocarbons—particularly in Utah.

The Uinta Basin area has not been extensively prospected for oil and gas, for (1) there is a lack of pronounced surface deformation, (2) depths to promising objectives are believed to be relatively excessive, and (3) market conditions are rather poor.

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COLORADO RIVER SALT BASIN

UTAH AND COLORADO

The Colorado River Salt Basin embraces 19,000 square miles in southeast Utah and southwest Colorado. The basin is featured by rapid changes in the character and thickness of as much as 7,000 feet of Paleozoic and Mesozoic strata, by relatively complex structure locally, by many salt intrusions, and by several lofty laccolithic groups. Known Pennsylvanian strata are salt, gypsum, anhydrite, shale, sandstone, and thick marine limestone; Permian and Triassic strata are largely non-marine reddish sandstone and shale, with some thin marine limestones; Jurassic (?) and Jurassic beds are mostly massive, gray to buff, non-marine sandstones; and Upper Cretaceous beds are conglomeratic sandstone overlain by marine shale. An unconformity of especial importance to oil-seekers separates Permian and Triassic strata, and others of lesser import are present higher in the section locally. Triassic and older formations thin northeastward toward the old Uncompahgre land mass in southwest Colorado, except where the Pennsylvanian Paradox formation is thickened abnormally by flowage.

Within the basin, natural gas has been found in Permian beds on anticlines at Last Chance and Woodside (Helium), and in Cretaceous and Jurassic beds at Cisco. Strong showings of oil have been found in wells in the Paradox formation in southern Grand County, Utah; and at many outcrops in Emery, Wayne, and Garfield counties, Utah, the White Rim sandstone member of the Cutler formation (Permian) is heavily saturated with oil, having yielded strong showings in at least two wells. At least twenty-five wells have penetrated as much as three-fourths—or more—of the sedimentary section, one on San Rafael swell and one at Cisco having reached pre-Cambrian rocks. Just outside the designated area carbon dioxide gas has been found in Permian beds at Farnham dome, rich helium gas in Jurassic beds at Harley dome, and normal gas in Cretaceous beds at Mancos Divide. The San Juan field, on San Juan River, has yielded small amounts of oil from Permian and Pennsylvanian strata in a syncline since 1908.

Uinta Basin

UTAH AND COLORADO

The Uinta Basin area covers 13,600 square miles in west-central Colorado and east-central Utah, being largely a major structural basin lying between major uplifts and abutting against the faulted Wasatch mountains on the west. It is believed that at least 20,000 feet of strata are present in the deeper parts of the area, ranging in age from Cambrian to Miocene. The deepest well in the area that drilled a normal section began in Upper Cretaceous marine shale and stopped in Pennsylvanian sandstone at a total depth of 7,173 feet. The records of this well and of other wells in and just outside the area indicate that the Paleozoic section is largely thick continental sandstone and shale, marine limestone, and some local evaporites; that Mesozoic beds are largely continental sandstone and shale at the top and bottom with intervening marine shale, and that the Tertiary section is continental sandstone and shale.

The unconformity observed at several places just outside the area that is of particular interest to oil-seekers in the area is that between the pre-Cambrian and overlapping beds—ordinarily Triassic or Jurassic—for wedges of intervening beds appear in short distances away from points of exposed overlap. Locally, however, older beds rest on the pre-Cambrian just outside the area, and within it most Tertiary formations have erosional unconformities at their bases.

Within the Uinta Basin area, small amounts of oil occur in Cretaceous beds at Rangely and DeBeque (probably Eocene, too) and some is present in Pennsylvanian beds in the former field. Gas occurs in Eocene beds at Piceance and White River domes, and just outside the area it is present in Permian, Jurassic, and Upper Cretaceous beds in several fields, that at Farnham and Garmesa being rich in carbon dioxide and that at Woodside and Harley being rich in helium. Fields just northeast of the area yield oil from Jurassic and Cretaceous beds, and in many parts of the area are deposits of oil shale, oil saturated sands, and numerous exposed veins of solid hydrocarbons—particularly in Utah.

The Uinta Basin area has not been extensively prospected for oil and gas, for (1) there is a lack of pronounced surface deformation, (2) depths to promising objectives are believed to be relatively excessive, and (3) market conditions are rather poor.

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Colorado River Salt Basin

UTAH AND COLORADO

The Colorado River Salt Basin embraces 19,000 square miles in southeast Utah and southwest Colorado. The basin is featured by rapid changes in the character and thickness of as much as 7,000 feet of Paleozoic and Mesozoic strata, by relatively complex structure locally, by many salt intrusions, and by several lofty laccolithic groups. Known Pennsylvanian strata are salt, gypsum, anhydrite, shale, sandstone, and thick marine limestone; Permian and Triassic strata are largely non-marine reddish sandstone and shale, with some thin marine limestones; Jurassic (?) and Jurassic beds are mostly massive, gray to buff, non-marine sandstones; and Upper Cretaceous beds are conglomeratic sandstone overlain by marine shale. An unconformity of especial importance to oil-seekers separates Permian and Triassic strata, and others of lesser import are present higher in the section locally. Triassic and older formations thin northeastward toward the old Uncompahgre land mass in southwest Colorado, except where the Pennsylvanian Paradox formation is thickened abnormally by flowage.

Within the basin, natural gas has been found in Permian beds on anticlines at Last Chance and Woodside (Helium), and in Cretaceous and Jurassic beds at Cisco. Strong showings of oil have been found in wells in the Paradox formation in southern Grand County, Utah; and at many outcrops in Emery, Wayne, and Garfield counties, Utah, the White Rim sandstone member of the Cutler formation (Permian) is heavily saturated with oil, having yielded strong showings in at least two wells. At least twenty-five wells have penetrated as much as three-fourths—or more—of the sedimentary section, one on San Rafael swell and one at Cisco having reached pre-Cambrian rocks. Just outside the designated area carbon dioxide gas has been found in Permian beds at Farnham dome, rich helium gas in Jurassic beds at Harley dome, and normal gas in Cretaceous beds at Mancos Divide. The San Juan field, on San Juan River, has yielded small amounts of oil from Permian and Pennsylvanian strata in a syncline since 1908.

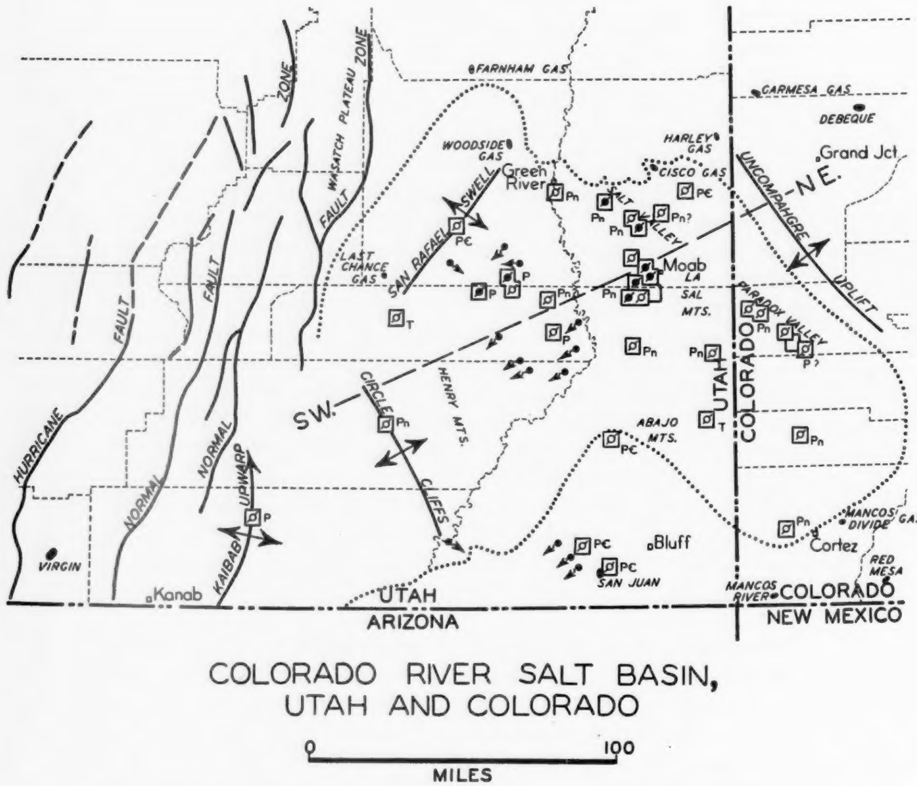

FIG. 22.—Map showing general features of Colorado River Salt Basin, Utah and Colorado. Area discussed within dotted line.

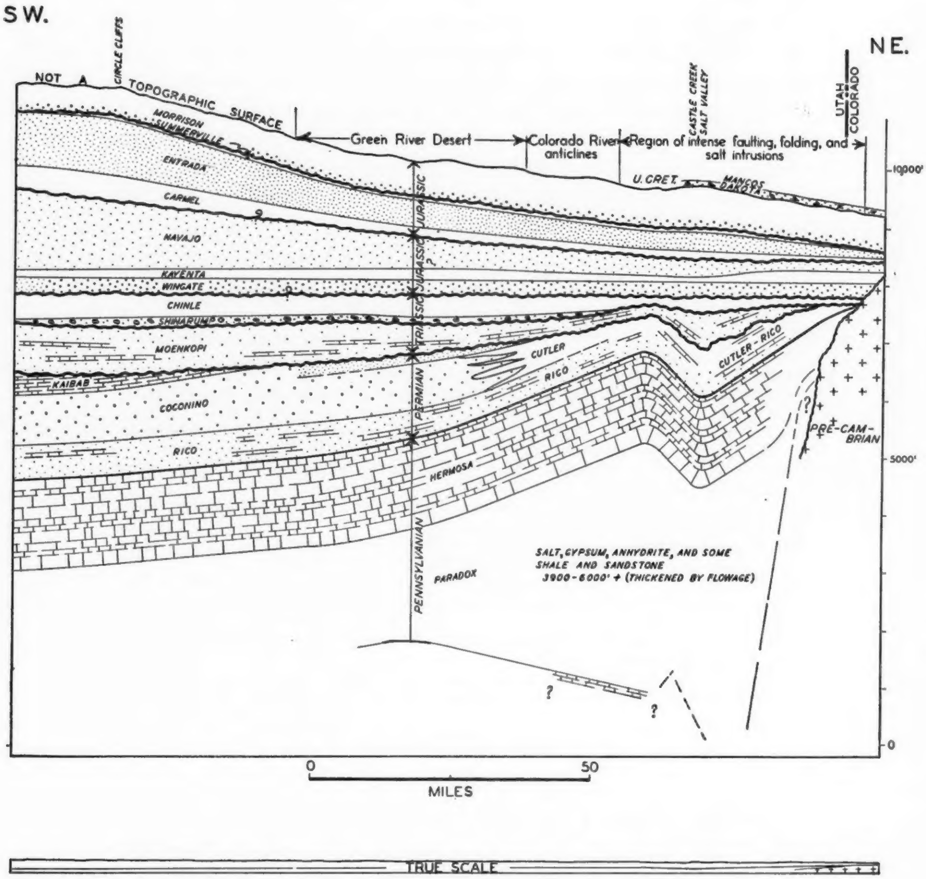

FIG. 23.—Generalized structure section across Colorado River Salt Basin in eastern Utah and western Colorado. See Figure 22 for line of section.

Development has not proceeded further in the Colorado River Salt Basin chiefly because of its inaccessibility. Most of the wells in the basin were drilled "on structure," without detailed knowledge of the regional structure. Many of the wells were drilled atop salt intrusions—in fact, one well in Paradox Valley, Colorado, started in salt and drilled 6,300 feet of it without finding its base—with the result that the detailed knowledge is largely lacking concerning the character and thickness of strata present along the flanks of the intrusions, and particularly about the unconformities that may be present there. In addition, there is no local market for gas, and any oil discovered probably would have to compete with markets now supplied by fields in Colorado, Wyoming, and California.

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Black Mesa Basin

ARIZONA AND UTAH

The Black Mesa Basin area covers 12,000 square miles in northeast Arizona and southeast Utah, being largely a broad, shallow structural basin modified on several sides by relatively small folds.

As 4,000 feet of Cambrian, Devonian, and Carboniferous strata crop out in the Grand Canyon just west of the Black Mesa Basin area and as 8,200 feet of beds ranging in age from Pennsylvanian to Upper Cretaceous, inclusive, crop out in and near the north portion of the area, it is probable that a relatively great thickness of strata of different ages lies below the Cretaceous cap rock in the central part of the basin, the lower half being largely marine and the upper half mostly

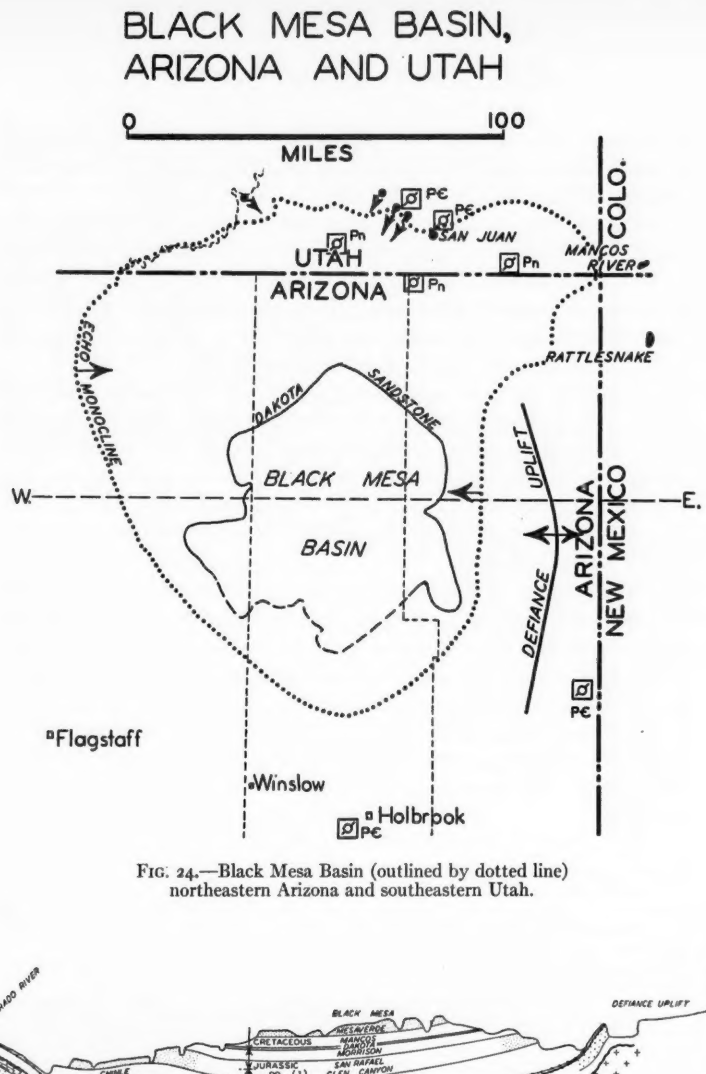

FIG. 24.—Black Mesa Basin (outlined by dotted line) northeastern Arizona and southeastern Utah.

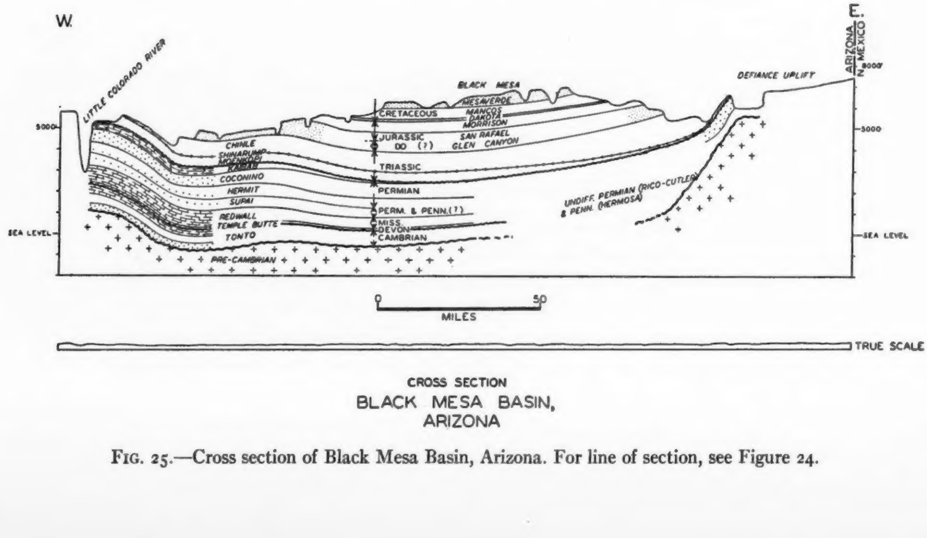

FIG. 25.—Cross section of Black Mesa Basin, Arizona. For line of section, see Figure 24.

continental. It is expected, too, that these concealed beds are featured by rather rapid wedging, overlapping, and varying of thickness and lithology, as they are at the outcrop.

Although there is a known widespread erosional unconformity at the base of the Triassic, presumably other unconformities elsewhere in the section, and possibly some local folding contemporaneous with late Paleozoic orogeny farther east, from the beginning of Upper Triassic (Chinle) time the rocks were relatively undisturbed by broad folding until affected by the Laramide revolution.

Small amounts of oil have been produced intermittently from Permian and Pennsylvanian beds in the shallow, synclinal San Juan field since 1908, and there are oil seeps in these beds along San Juan River and in Triassic beds northwest of the area. Oil is produced from Cretaceous beds in the small Mancos River field, southwest Colorado, and from Cretaceous and Pennsylvanian strata in the Rattlesnake field, northwest New Mexico.

As no water occurs in known oil-bearing strata on anticlines in the northern part of the area, it is possible that more oil will be found in synclines in some parts of the area. It is possible, too, that oil will be found in those parts featured by the wedging, changing in lithology, and overlapping of Paleozoic strata.

The Black Mesa Basin area has not been prospected more thoroughly for oil and gas, for (1) wells drilled on anticlines in the northern part of the area were dry and (2) market conditions are rather unfavorable.

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SAN JUAN BASIN

NEW MEXICO AND COLORADO

The San Juan Basin area covers 12,000 square miles in northwest New Mexico and southwest Colorado, being bordered on all sides by major uplifts. As a well in the Rattlesnake field just west of the area started in Upper Cretaceous marine shale and drilled 7,407 feet to Upper Cambrian quartzite, it is believed that about 14,000 feet of beds are present in the central part of the area, the youngest being

Eocene. Ordovician and Silurian beds are probably absent; Pennsylvanian, Mississippian, and Devonian (?) strata are mostly marine limestone; Permian, Triassic, Jurassic (?), and Jurassic beds are mostly

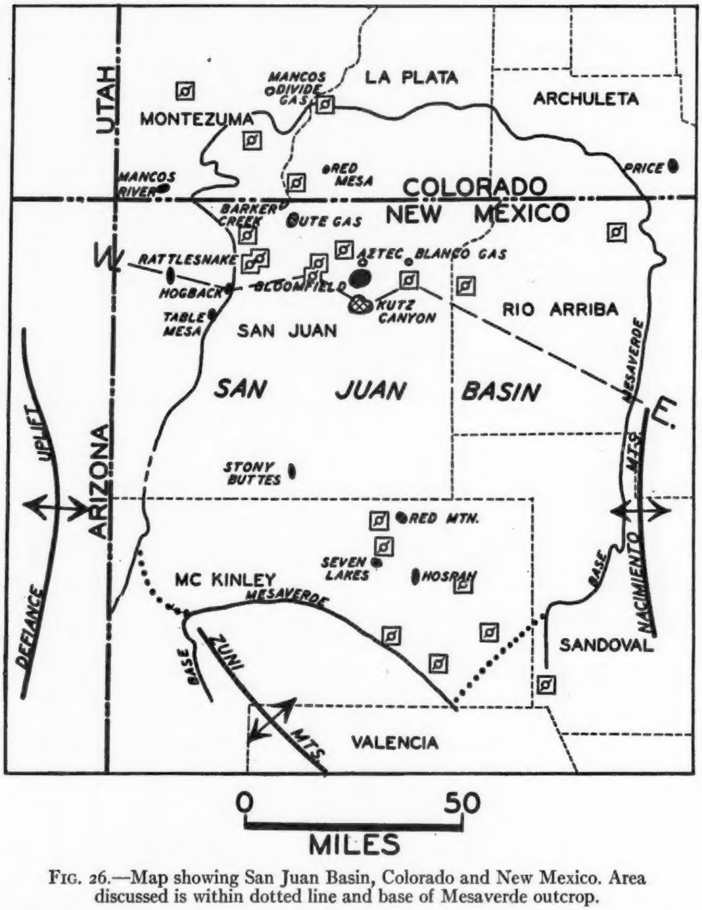

FIG. 26.—Map showing San Juan Basin, Colorado and New Mexico. Area discussed is within dotted line and base of Mesaverde outcrop.

redbeds; Upper Cretaceous beds are an alternating series of marine and non-marine sandstone and shale; and Tertiary beds are fresh-water sandstone and shale. As no wells have been drilled below the Upper Cretaceous in the central part of the area, no details are available concerning the character and relations of lower beds there. As

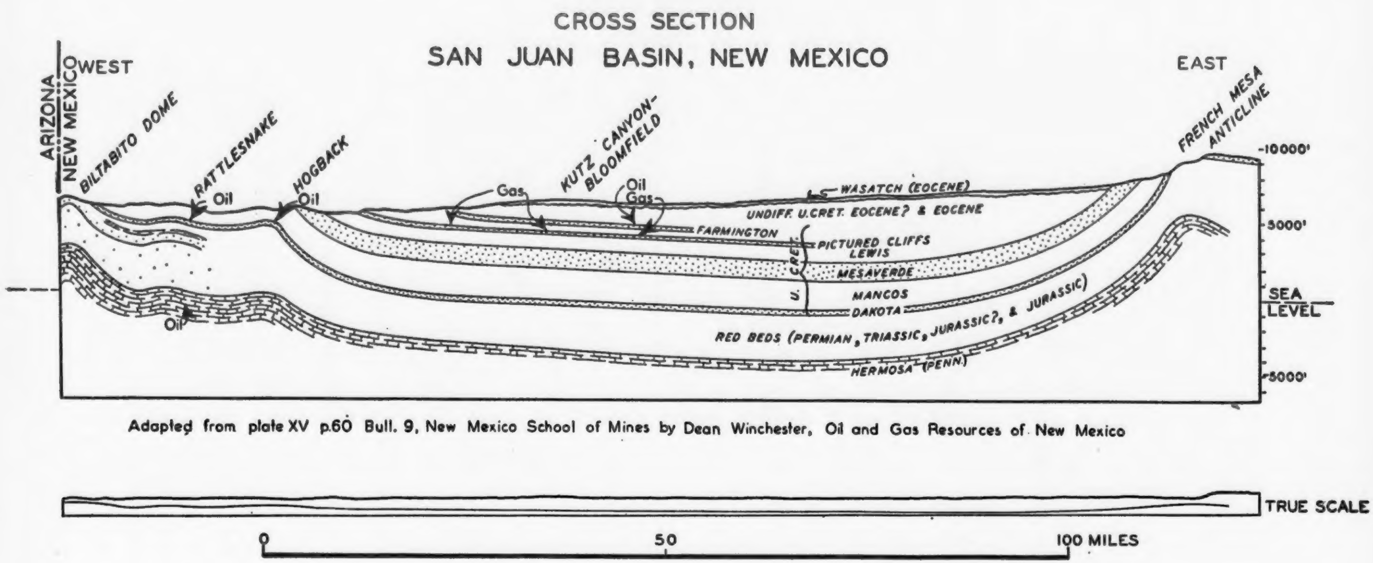

FIG. 27.—Generalized structure section across San Juan Basin, northwestern New Mexico. See Figure 26 for line of section.

shown in the cross section, the basin is broad, and relatively shallow.

Most of the anticlines and domes in and near the San Juan Basin have not been tested below the Dakota sandstone (Upper Cretaceous), but one—Rattlesnake—has been drilled to the Upper Cambrian. As shown on the map, there are about 16 localities in and near the basin that have yielded varying amounts of oil or gas, all producing from Upper Cretaceous beds and one—Rattlesnake—also producing from Pennsylvanian beds. Eight of the proved structures are relatively unfaulted anticlines, three are faulted anticlines, and five are very gentle monoclines—such as Kutz Canyon, Aztec, Bloomfield, Blanco, Seven Lakes, and Mancos River. All Upper Cretaceous production is from sandstones, except that obtained from the Mancos shale in the monoclinal Mancos River field, Colorado. Locally the gravity of the oil from Upper Cretaceous beds is exceptionally high—63° to 76° at Rattlesnake and 63° at Hogback—whereas Pennsylvanian oil at Rattlesnake is 42°.

Development in the San Juan Basin area has been very slow because of no known pronounced surface deformation in non-producing areas and because of expected excessive drilling depths to promising objectives.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 25, NO. 8 (AUGUST, 1941), PP. 1508-1526, 10 FIGS.

POSSIBLE FUTURE OIL PROVINCES OF NORTHERN MID-CONTINENT STATES

TULSA GEOLOGICAL SOCIETY[1]
Tulsa, Oklahoma

NORTH AND SOUTH DAKOTA

This area comprises approximately 100,000 square miles. It is underlain by 1,000 to 12,000 feet—an estimated average of 1¼ miles—of chiefly marine sediments, or a gross volume of 125,000 cubic miles. The sediments include representatives of nearly the complete geologic column from the pre-Cambrian through the Paleozoic, the Mesozoic, and the Cenozoic.

The 6,000 feet of sediments in the vicinity of the Black Hills consist of approximately 67 per cent shales, 15 per cent limestone, and 18 per cent sandstone. Some gypsum and other evaporite beds are present which increase somewhat toward the east. In a known drilled section of 10,000 feet in northwestern North Dakota, the sandstones have decreased to 1 per cent, the shales to 47 per cent and the limestone and dolomite increased to 47 per cent. About 1 per cent of the section is evaporite salt and gypsum. From west to east across both of the Dakotas, there is a gradual loss of sedimentary section, either by truncation and overlap or non-deposition, to the Minnesota border where Cretaceous to Jurassic rocks rest unconformably on rocks of Devonian to pre-Cambrian age. Due to this eastward overlap, there must be several large wedge belts of porosity extending throughout much of the 400-mile distance from north to south. Other wedge belts are generally known to occur in the Ordovician north of the Black Hills, in the upper Mississippian across southern Montana and into North Dakota, and on the south against the westward extension of the Sioux uplift into northern Nebraska.

Significant regional unconformities are known at the base of the Cretaceous, the base of the Jurassic, the base of the Pennsylvanian, and the base of the Mississippian. However, but little is known as yet of the details concerning the geologic relations adjacent to these unconformities.

Generally, the structure of this region is that of a broad, low-dipping basin interrupted by one major uplift, the Black Hills in southwestern Dakota, and a lesser fold, the Baker-Glendive anticline,

[1] Committee consists of L. Murray Neumann, chairman, Carter Oil Company; C. G. Carlson, consulting geologist; A. R. Denison, Amerada Petroleum Corporation; J. V. Howell, consulting geologist; D. C. Nufer, Burke-Greis Oil Company; R. J. Riggs, Stanolind Oil and Gas Company; and T. E. Weirich, Phillips Petroleum Company.

in eastern Montana and western North Dakota. The deepest part of the basin is in western North Dakota, where it is called the Williston basin, and its southern extension into South Dakota where it has been called the Lemmon syncline. In broad terms, the Williston basin may be considered as the southern end of the great structural and sedimentary unit extending throughout the Plains region of Saskatchewan and Alberta in Canada.

Evidences of oil and gas in the Minnelusa sands (Pennsylvanian) are found in several wells drilled south of the Black Hills; in the production on the Baker-Glendive anticline where gas is produced in the Eagle sand (Cretaceous) and oil in the Mississippian and Devonian?; in the showings of gas throughout a large part of central South Dakota and at several points in North Dakota from Cretaceous sands, chiefly in the Dakota group; and in the showings of oil in sands of the Pennsylvanian and Ordovician formations north of the Black Hills. The nearest commercial production is found at Lance Creek, Wyoming, 80 miles southwest of the Black Hills, from rocks of Cretaceous, Jurassic, and Pennsylvanian age, similar to those in parts of the Dakotas.

Exploration in this area probably has been retarded chiefly because of its distance from the large markets; the cover of glacial and Tertiary unconsolidated sands and gravels in a large part of the area; the fact that the known surface structures generally are of low relief and that several known closed structures within the area, as well as several large closed folds in the neighboring parts of Nebraska, Wyoming, and Montana, have been found to contain neither oil nor gas, in tests, of which some reached the pre-Cambrian; and to the fact that the large fold known as the Baker-Glendive anticline has not so far been proved as productive as its size and geologic setting would seem to justify.[2]

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[2] Another deep test well is drilling on this anticline which is expected to penetrate older rocks than have heretofore been tested.

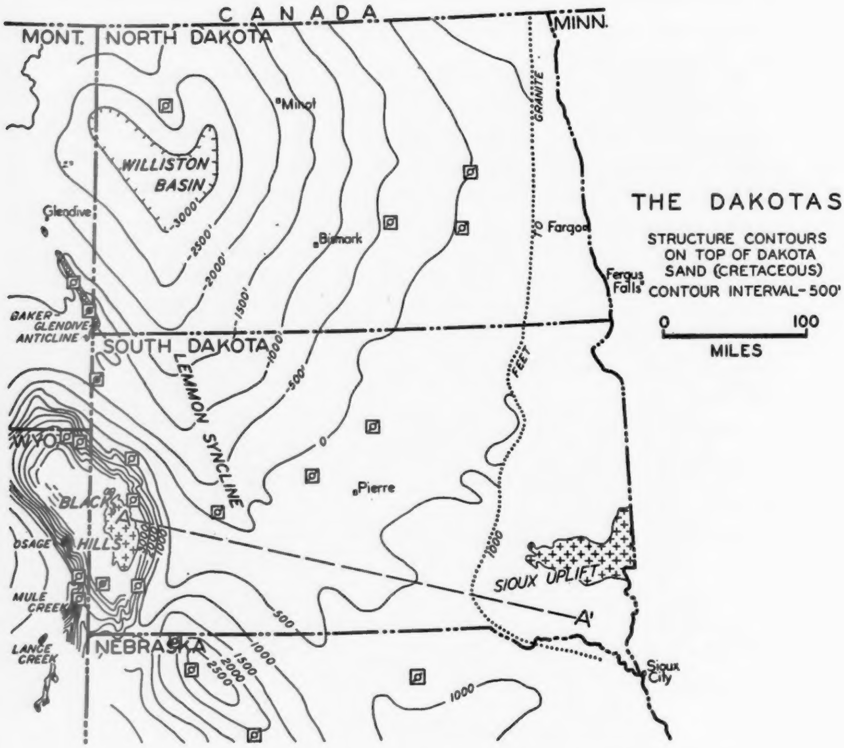

FIG. 1.—Map showing general features of North and South Dakota. Area in Dakotas which is described is west of dotted line.

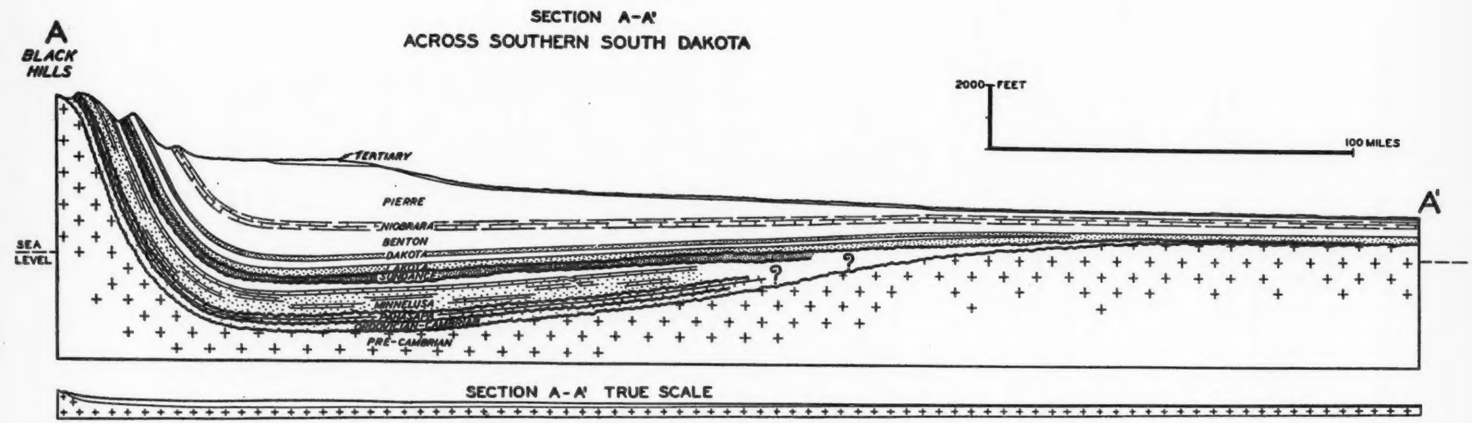

FIG. 2.—Generalized structure section across southern South Dakota along line AA' shown in Figure 1.

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WESTERN NEBRASKA

The possible northward extension of the central Kansas uplift is another area of possible future oil and gas production. Unlike most areas discussed in this symposium, the structure is that of a buried uplift. It is an area of repeated deposition, uplift, and erosion. As herein considered, it comprises the western part of Nebraska as outlined on the map (Fig. 3) by the heavy-dotted line. Within this area, which is cross-hatched, it is believed that little or no Mississippian sediments are now present.

This area is approximately 40,000 square miles and its boundaries are indefinite. The sediments, which are both marine and non-marine, vary from 3,500 feet to 4,500 feet in thickness. They consist chiefly of shales and sandstones, with minor amount of limestone, anhydrite, and dolomite. The approximate volume of sediments available for exploration is on the order of 30,000 cubic miles.

The age of these sediments ranges through the greater part of the geologic column. There is present thick Tertiary sandstone and gravel, Cretaceous shales, sandstone, and chalky limestone; Permian and Triassic red shales, sandstone, gypsum, anhydrite, and dolomite; Pennsylvanian shales, thin limestones, and thin sandstones. Along the margins of this uplift, limestones of Ordovician and Cambrian age are thought to be present.

The structure of this feature is broadly anticlinal. Several periods of folding extending from pre-Cambrian to early Pennsylvanian, have occurred. The most intense period of orogeny occurred in early Pennsylvanian (post-Morrow, pre-Des Moines) time, similar to that common to many other parts of the Mid-Continent region. Most of the post-Paleozoic movements in the area probably consist of regional tilting in pre-Cretaceous and post-Tertiary time.

This combination of conditions—consisting of uplift, erosion, and overlapping deposition in the Paleozoic rocks—is considered favorable for the accumulation of oil. The accumulation may be in anticlinal folds, in lenses of sands, or in the wedge edges of truncated porous beds.

The early Paleozoic unconformities are now, for the most part, obscured by the one large pre-Pennsylvanian unconformity. The an-

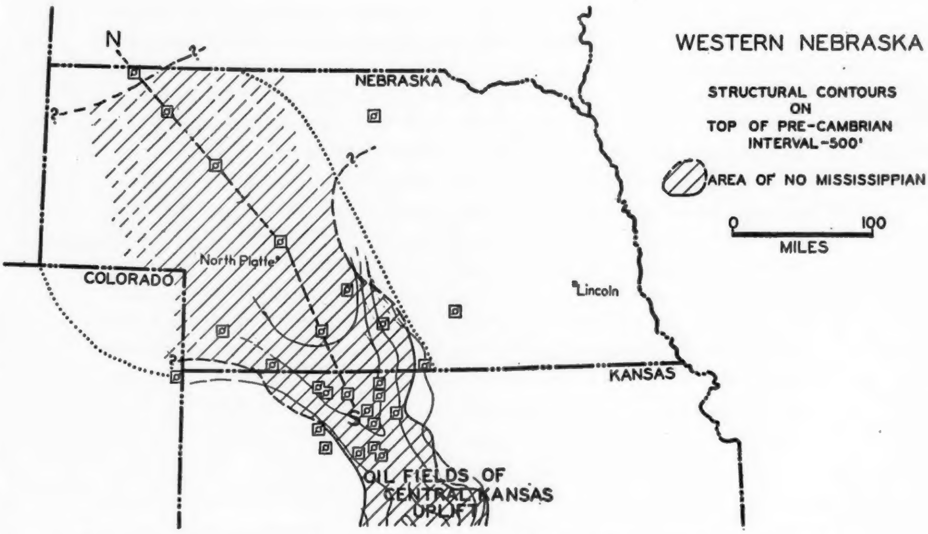

FIG. 3.—Map showing general features of western Nebraska. Area discussed is within dotted line.

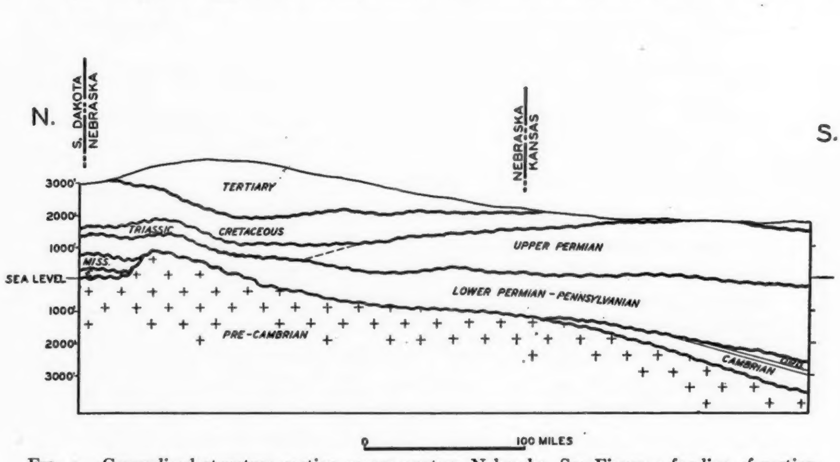

FIG. 4.—Generalized structure section across western Nebraska. See Figure 3 for line of section.

ticipated accumulations of oil may, therefore, be divided into two groups: accumulation to be found in sediments below or at the unconformity, and accumulation found in sediments above this unconformity. Thus, oil pools found above this break would be controlled chiefly by the attitude of the porous sediments, and those pools found below would be controlled by topography and the variable porosity of the leached and eroded limestones, or wedge edges of porous beds.

Exploration of this area has been largely handicapped by the presence at the surface of thick Tertiary sands and gravels. These deposits not only obscure the structure of the pre-Tertiary beds, but also blanket the area in such a way as to make uncertain the results of detailed geophysical exploration. Much geophysical work has been done in parts of this region with uncertain results. Some core drilling has been done, but this work merely shows the attitude of the Cretaceous beds, and then only in an area where the Tertiary sands and gravels are thin. Thus, the common structural methods of exploration have so far been without success.

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SALINA AND FOREST CITY BASINS

KANSAS, NEBRASKA, IOWA, AND MISSOURI

The structure map presented herewith shows 500-foot contours drawn on top of the Arbuckle (Ordovician) limestone. Two closed basins are shown, separated by the Nemaha granite ridge—they are the Forest City basin on the east and the Salina basin on the west. Dry holes shown are only those which were drilled to the Arbuckle or deeper. In the Forest City basin there are 47 or more such wells, 16 of which were drilled to pre-Cambrian rocks. In the Salina basin, there are 40 or more such wells, 7 of which were drilled to the pre-Cambrian. The character of the sediments varies as shown by the cross section, but may be divided into four units, and may be described as follows from the surface down: (1) Cretaceous marine shale above with Dakota sandstone at base; (2) Permian and Pennsylvanian interbedded marine shales and limestone with a basal shale-sandstone series, largely marine; (3) "Mississippi lime" to Arbuckle, marine

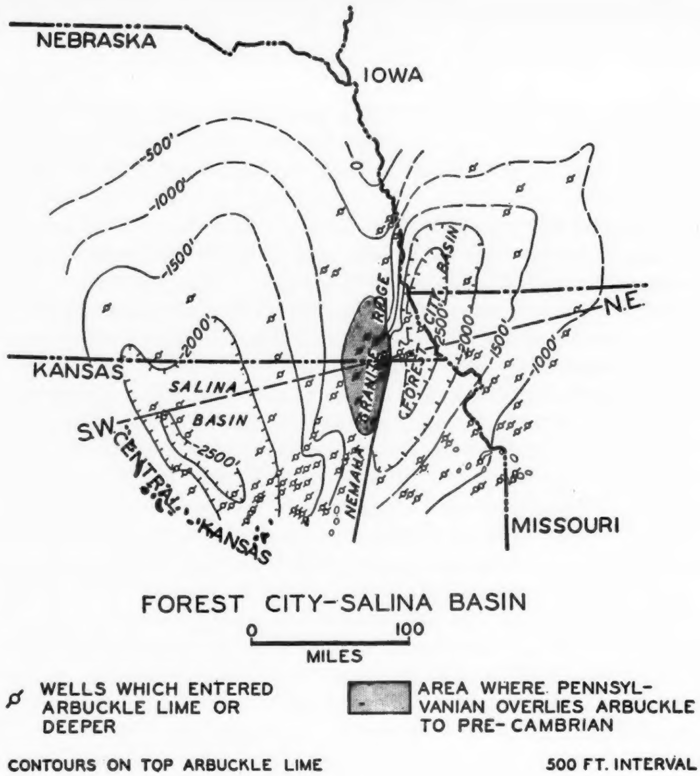

FIG. 5.—Structure map of Forest City-Salina basin region of Nebraska, Missouri, and Kansas.

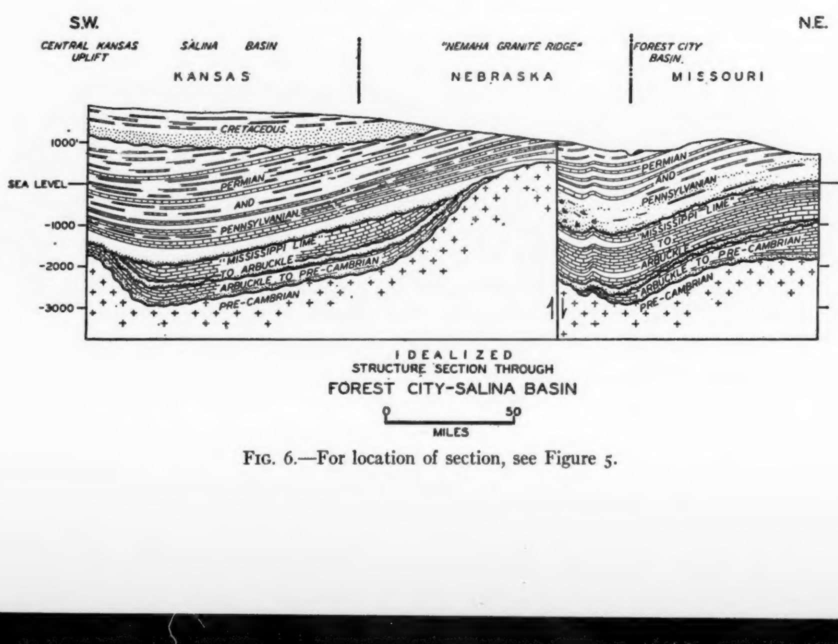

FIG. 6.—For location of section, see Figure 5.

limestones, and dolomite with chert, and a shale-sandstone series at the base, of marine origin; (4) Arbuckle to pre-Cambrian, marine dolomites, and limestone with a basal sandstone—all of essentially marine character.

There are approximately 60,000 square miles in the area under discussion, having more than 1,000 feet of sediments overlying the basement rocks. The maximum thickness is 4,500 feet and the average thickness 3,000 feet; thus, approximately 36,000 cubic miles of essentially marine beds are available for exploration.

Oil production occurs at one locality in the Forest City basin, namely, the Falls City pool in the southeastern corner of Nebraska, where the oil is found in the Hunton limestone of Devonian age on a closed anticline. Two other one-well producing areas are near by. The Lost Springs pool and the Roxbury pool, Kansas—both producing from the "Mississippi lime" associated with anticlinal structure—are on the southern border of the Salina basin and by some are included within the basin. Aside from these there have been numerous showings of oil reported from wells within these two basins in beds ranging in age from Pennsylvanian to Arbuckle, the more important of which have been in wells drilled between the towns of Lindsborg and Salina, Kansas. The prolific Central Kansas uplift pools flank the Salina basin on the southwest and the oil fields of central Kansas and the Nemaha granite ridge are just beyond its borders at the south. South of the Forest City basin are the numerous oil fields of Greenwood and adjacent counties in eastern Kansas. Some of the oldest oil and gas pools of the Mid-Continent region border the Forest City basin on the southeast around Kansas City. These two basins then may be said to be bounded on the southwest, south, and southeast by commercial oil and gas production.

There is a pronounced and universal unconformity at the base of the Cretaceous, and other unconformities of varying importance occur below the Mississippian, but the outstanding hiatus of the entire area occurs at the base of the Pennsylvanian. The uplift and subsequent erosion of the Nemaha granite ridge brings the basal Pennsylvanian sandstone into contact with the beveled edges of rocks ranging in age from Mississippian to pre-Cambrian. Each of these truncated formations provides possibilities for porosity wedges which combine to give an almost unlimited range of favorable conditions. East of the granite ridge, thick lenticular sandstones are present in the basal Pennsylvanian, partially derived from erosion of the ridge itself. These give opportunity for the sand lens or shoestring type of oil accumulation.

A large part of the Salina basin is covered by Cretaceous rocks

which do not accurately reflect the attitude of the older possible oil-bearing beds. These same sediments apparently make geophysical work more difficult or less certain of interpretation, and only a limited amount of this type of work has been done. Surface structures in Pennsylvanian and Permian rocks, as those along the Abilene arch, were long ago drilled and were uniformly dry.

A considerable part of the Forest City basin is covered with glacial drift which has made surface mapping difficult, or in places impossible. Such surface structures as have been found and drilled have been dry. Due to minor unconformities, the Pennsylvanian beds at the surface may not accurately reflect the structure in the older beds such as the Devonian, which has been found productive in southeast Nebraska.

The discovery of the one commercial oil field in the Forest City basin is credited to seismograph work. Prior to 3 years ago very little prospecting of this kind had been done. Since such prospecting began, however, very few wells have been drilled solely on seismic information; hence, the efficiency of this newer exploratory tool has not yet been fully tested.

In summary, the sequence of sedimentation, the evidence of major structural movements, and the total quantity of marine sediments are not greatly dissimilar to that in near-by areas where large quantities of oil have been found. For an area of this size, an exceptionally large number—87 or more—of wells have been drilled through more than three-fourths of the stratigraphic section (23 to pre-Cambrian) without finding more than a few small oil fields. Numerous surface and some seismograph structures have been drilled and found dry. The failure of the various exploration methods used, from the early wells drilled on surface evidence to the later wells drilled on core drill and seismograph evidence, combined to retard more drilling and development in these two basins.

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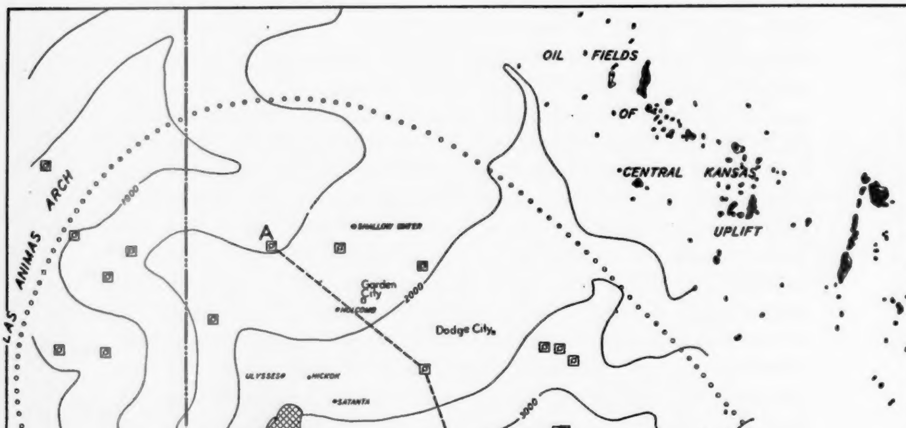

FIG. 7.—Map showing general features of the Anadarko-Panhandle region of western Oklahoma and adjacent parts of Kansas, Colorado, and Texas. Area described lies within dotted line.

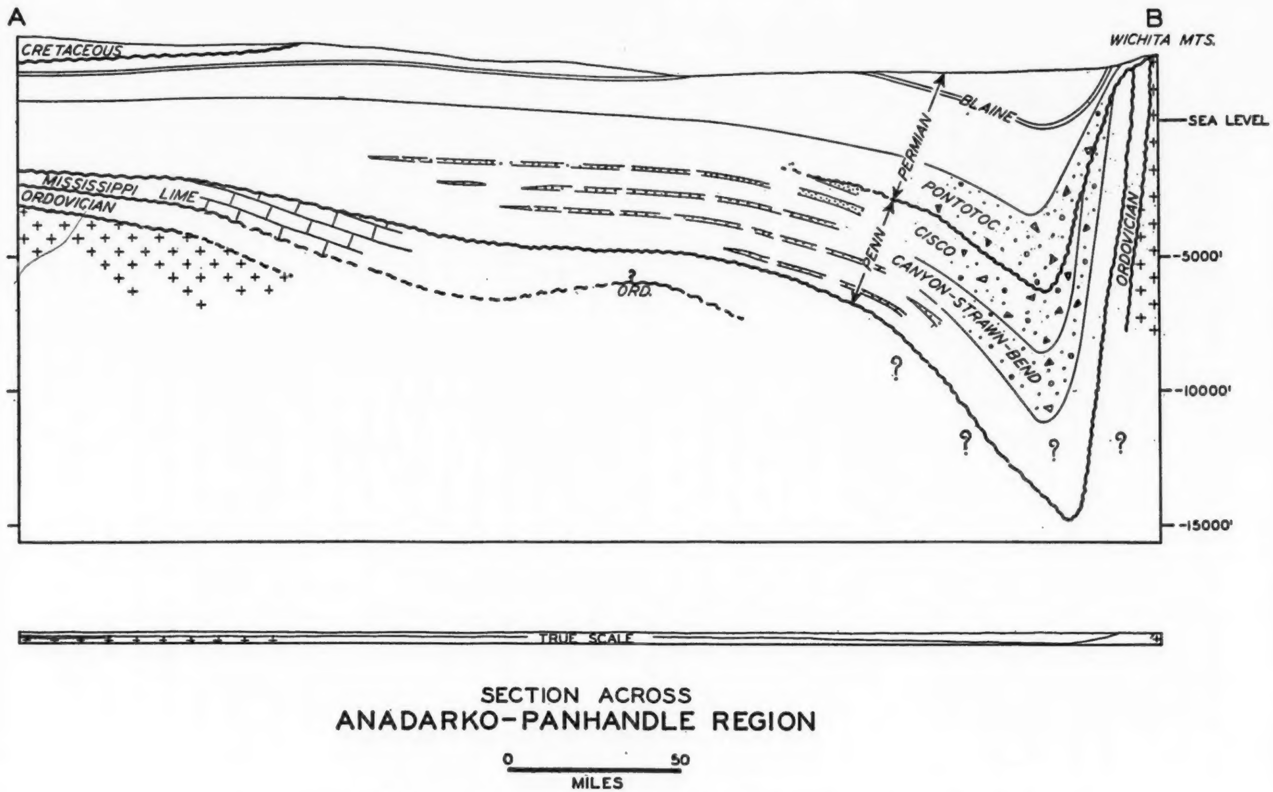

FIG. 8.—Generalized structure section from north to south across Anadarko basin. Line of section is shown in Figure 7.

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ANADARKO-PANHANDLE REGION

OKLAHOMA, KANSAS, TEXAS, AND COLORADO

This region is an area of approximately 140,000 square miles. It is bounded on the south by the Wichita Mountains in Oklahoma and the Amarillo buried ridge in the Texas Panhandle; on the west by the Sierra Grande-Las Animas arch of New Mexico and Colorado; on the north by the Central Kansas uplift; and on the east by the southwest-dipping homocline of central Oklahoma. The structure of the region is shown on the accompanying map (Fig. 7) by contours drawn on top of the "Mississippi lime" at 500-foot intervals.

The sedimentary rocks of the region consist chiefly of marine Paleozoic formations from the Cambrian to and including the Permian, with thin representatives of the Mesozoic, Cenozoic, Tertiary, and Recent covering much of the area. The average thickness of the sedimentary column is approximately 2 miles, or a total volume of 280,000 cubic miles of sediments. The thickest section of the region occurs at the bottom of the Anadarko basin where more than 3 miles of sediments exist. This is known since one test well was drilled to nearly 15,000 feet without completely penetrating the Pennsylvanian section.

Structurally, the region is a broad syncline with the deepest part along the south side adjacent to the Amarillo-Wichita belt of folding, where it is known as the Anadarko basin. The rocks dip steeply north from this area of folding and then rise from the bottom of the syncline gradually north and west to the boundaries in southeastern Colorado and southwestern Kansas. The syncline opens out to the southeast where it joins the Ardmore syncline and passes under the Cretaceous overlap into north Texas.

Considerable drilling has been done around the edges of this region, but within the area, relatively few wells have been drilled. Of these,

several have had showings of oil and gas. Around the edges of the region, however, many oil fields are found, producing from rocks ranging in age from Permian to Ordovician, and these rocks are all known to underlie the Anadarko-Panhandle region.

Three important regional unconformities are found within this region: one at the base of the Pontotoc formation; one at the base of the Pennsylvanian system; and one at the base of the Chattanooga or Woodford shale of Mississippian age. Folding occurs below each of these unconformities in the surrounding territory, where much oil is found associated with such folding.

Upwards of a thousand linear miles of sedimentary wedges of porosity are known to occur within the region. In part, this is the result of overlap by the Pontotoc formation along much of the length of the region on the north side of the Wichita-Amarillo belt of folding; and, in part, it is the result of a northward and westward gradation of several thousand feet of sandstone into the shales and limestones of northern Oklahoma and southern Kansas. Additional drilling undoubtedly will develop many additional wedges of porosity, since the stratigraphic column generally is characterized by lateral gradation, overlap, and lithologic variation.

Development in the region has been retarded largely because the nature of the surface rocks does not permit reliable surface mapping, and the shallower sediments in much of the region contain evaporites which have made geophysical interpretation difficult. The result is that relatively little is known of the details of structure within the region. While the general opinion that the Ordovician will be found at depths on the order of 10,000 to 15,000 feet has retarded drilling, it is recognized that the presence of the regional unconformities with known pre-unconformity folding in the surrounding territory may bring the deeper formations to much shallower depths. So far, attempts to find such a situation have failed, and, in spite of the many geological factors favorable to oil accumulation, this region still presents as big a problem in exploration as ever.

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SOUTHEASTERN OKLAHOMA-NORTHWESTERN ARKANSAS

The area includes approximately 12,500 square miles with a thickness of sediments ranging from 3,000 to perhaps 15,000 feet. Of the area considered, 10,000 square miles are in the basin, and about 2,500 square miles in the frontal belt of the Ouachita Mountains. The average thickness of sediments is approximately $1\frac{1}{2}$ miles and the gross volume of sediments is 18,750 cubic miles.

In the northern and northwestern parts of the area, the pre-Mississippian beds include a more or less complete section of Paleozoic rocks ranging from upper Cambrian through Mississippian with numerous unconformities and local overlaps. The facies of deposition here is of the Ozark or Arbuckle type, with marine shales, limestone, and "Wilcox" type sands in the Ordovician. In the southern area, south of the Choctaw fault, the pre-Pennsylvanian facies is of the Ouachita type, with predominantly siliceous shales, novaculites, cherts, and thick bodies of sandstone. Although the Ouachita area is now an anticlinorium, it is clearly the site of an ancient geosyncline of great depth.

While the time range of the Paleozoic beds deposited in the localities of the present Arbuckle and Ouachita mountains is the same, and many of the individual units can be correlated, the lithology of the two facies is so different that the relation between their respective sites of deposition is not apparent. Either two separate basins were involved, or the lateral gradation occurred over a considerable distance, which is now greatly reduced by extensive overthrusts.

In general, the Ouachita facies does not appear suitable for accumulation of oil on account of the low porosity and some degree of metamorphism. The Ozark-Arbuckle facies, however, is composed entirely of rocks identical with those of the producing areas of the Mid-Continent and may be considered to be favorable. The only obviously unfavorable factor is presence of quartzitic Wilcox sand in a deep test at Quinton, Oklahoma, which suggests the existence of the Ouachita siliceous facies in the McAlester-Arkansas Valley geosyncline, but requires confirmation in other areas to be sure it is more than a local occurrence.

Obviously, if the change from Ouachita to Ozark-Arbuckle type sediments occurs through lateral gradation, we do not at present know the location or extent of this gradational zone since it is presumably buried beneath the surface in the Arkansas geosyncline or the Ouachita

Mountains. If the difference in facies is due to a barrier, however, it too is buried beyond observation.

Assuming that Arbuckle-Ozark beds are the most likely source of oil and gas, the numerous seeps and asphalt deposits of the frontal zone suggest that here, at least, the Ouachita thrusts may have overridden rocks of Arbuckle type, and that eventually oil in commercial quantities may be produced in traps beneath the frontal overthrusts.

A great thickness of Pennsylvanian rocks, almost wholly clastic, chiefly shales, fills the Arkansas River Valley basin located between the Ozark Mountains and the Ouachita Mountains. In these sediments, organic remains are rather generally distributed, coal beds are widespread in the upper portion, and gas is produced in a number of small fields along the Arkansas-Oklahoma line in reservoirs of anticlinal structure. Many additional folds occur throughout the basin, trending generally east-west and readily mappable in the Pennsylvanian surface rocks. Thrust faulting does not exist north of the Choctaw fault zone, and the basin folds are relatively gentle and unbroken.

Unconformities exist throughout the geologic column, some sixteen being reported in the rocks of the Ozark Mountains alone. The most important, however, is that at the base of the Chattanooga shale, which is known to rest variously on all formations from pre-Cambrian to Devonian. In general, along the southern border of the Ozarks, the Chattanooga rests on some part of the Ordovician. Farther out in the basin, however, scattered wells have shown the presence of a full section of Silurian and Devonian rocks beneath the Chattanooga, these being overlapped along the north slope of the basin. Such a condition of pre-Chattanooga wedging affords opportunities for accumulation of oil and gas.

No oil is being produced in the basin, but a number of productive gas fields occur and are shown on the map (Fig. 9). The nearest oil production is in the Okmulgee district of Oklahoma, to the northwest, and is from the same section known to exist also in the area discussed.

Exploration of the area appears to have been retarded by fear of the relatively high carbon ratios of coals in the Pennsylvanian beds in the central part of the basin, and because a number of definite anticlines have been devoid of oil or have produced only gas.

Inasmuch as very few test wells have been drilled below the Pennsylvanian in the deeper parts of the basin and fewer still below the Mississippian, and since a great many favorable structures remain to be tested, the ultimate possibilities are still unknown. Much more geologic study and additional drilling are required to determine the possibilities of this province.

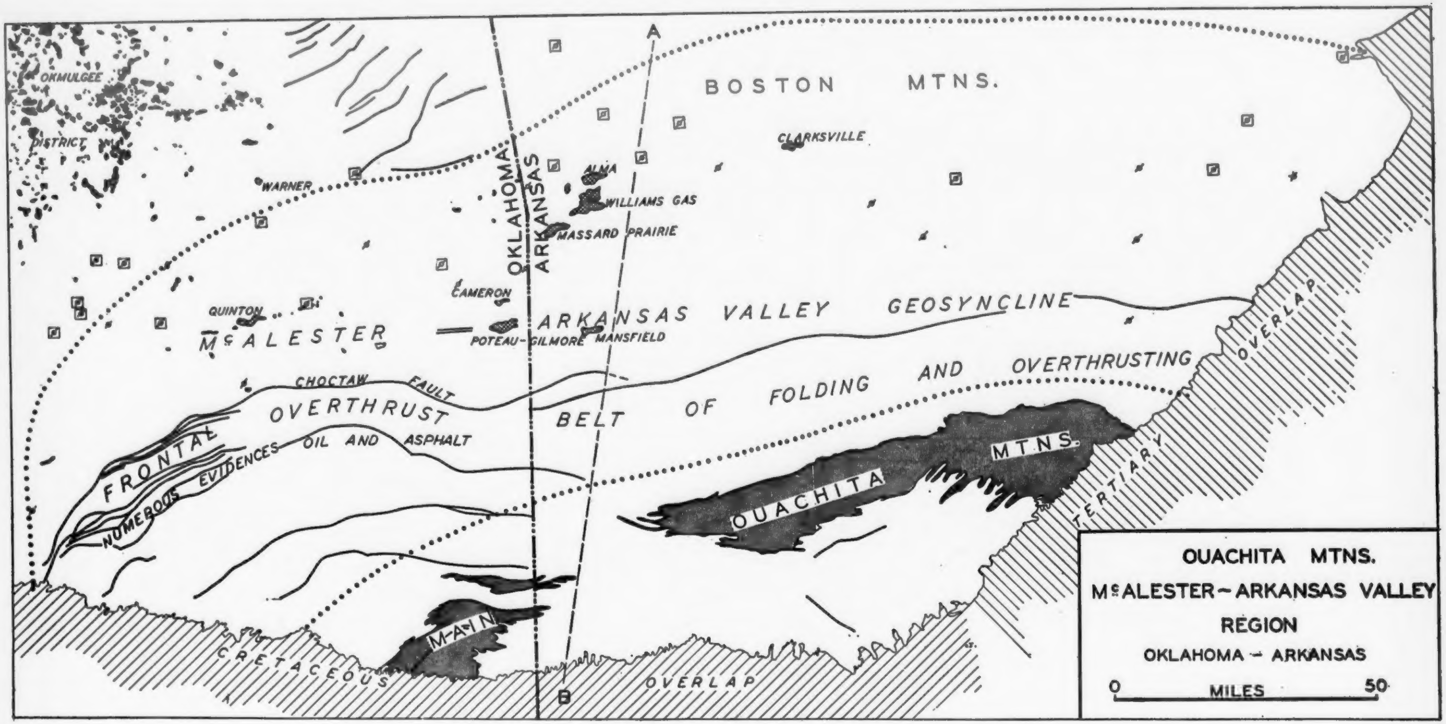

FIG. 9.—Map showing some of general features of McAlester-Arkansas River Valley-Ouachita Mountain region in eastern Oklahoma and western Arkansas
Area described lies between dotted lines.

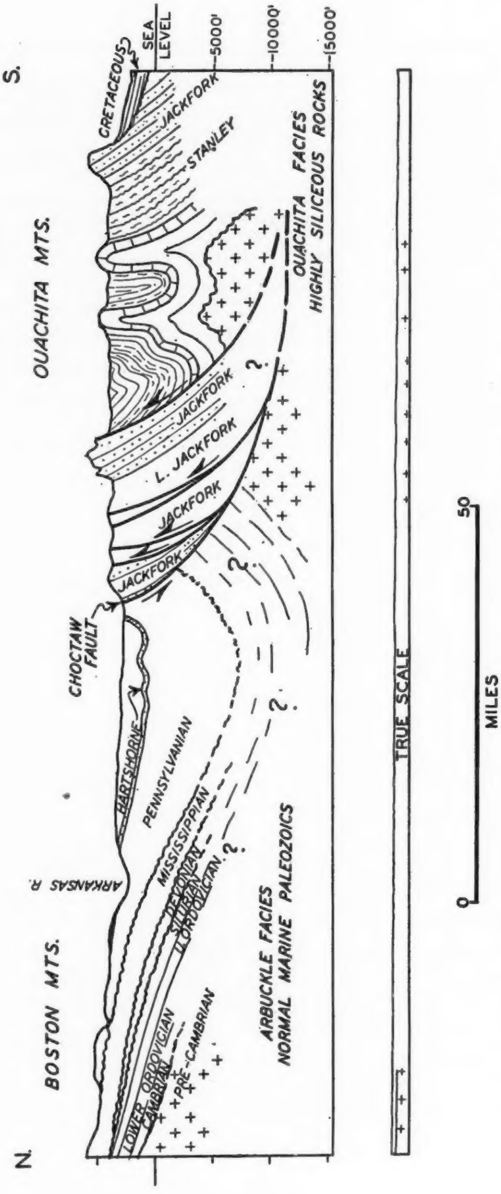

FIG. 10.—Generalized north-south structure section across Arkansas River Valley-Ouachita Mountain area in western Arkansas. Line of section is shown in Figure 9.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 25, NO. 8 (AUGUST, 1941), PP. 1527-1538, 6 FIGS.

POSSIBLE FUTURE OIL PROVINCES OF WEST TEXAS

WEST TEXAS GEOLOGICAL SOCIETY[1]
Midland, Texas

NORTHERN LLANO ESTACADO

The area comprises about 40,000 square miles between the pre-Cambrian outcrops of New Mexico on the west, the Rio Bravo and Amarillo uplifts on the north, the Red River uplift on the east, and the Permian basin oil fields on the south. The average thickness of sediments is about 10,000 feet and the total volume of sediments about 76,000 cubic miles.

Permian rocks are present over this whole area and make up about half of the total volume of sediments. Structurally they rise from the north end of the Midland basin toward the west, north, and east. The Permian system contains a much larger proportion of redbeds and evaporites here than in the present producing part of the Permian basin on the south. Prospects for oil in the Permian are best in the basal formation which is generally a solid dolomite and limestone with shale in the upper part and interbedded granite wash on the flanks of uplifts.

The systems younger than the Permian are less likely to contain oil. The Triassic consists entirely of redbeds. Nevertheless, a few oil showings have been reported, and asphalt occurs near Santa Rosa, New Mexico.[2] The Jurassic exists only as a thin remnant in the northwest corner of the area. Thin eroded patches of Cretaceous limestone, shale, and sandstone are present over the western half of the area. Tertiary sands and clays of continental origin form the surface covering of the Llano Estacado.

The systems older than the Permian may be preserved in a great basin which is masked by the Permian beds. The trough occupies most of the area and has an east-west trend. Deep wells have been drilled on the buried pre-Cambrian ridges north and south of the trough, but tests in the trough, except at the eastern and western ends, have not been taken below the Permian. Some of the Paleozoic formations in the area may contain oil, because the Permian basin fields to the south produce at present from the Cambrian, Ordovician, Silurian,

[1] Committee consists of John M. Hills, consulting geologist; T. S. Jones, Humble Oil and Refining Company; and Robert E. King, Shell Oil Company, Inc.

[2] Dean E. Winchester, "Oil and Gas Resources of New Mexico," *New Mexico School of Mines Bull. 9* (1933), p. 208.

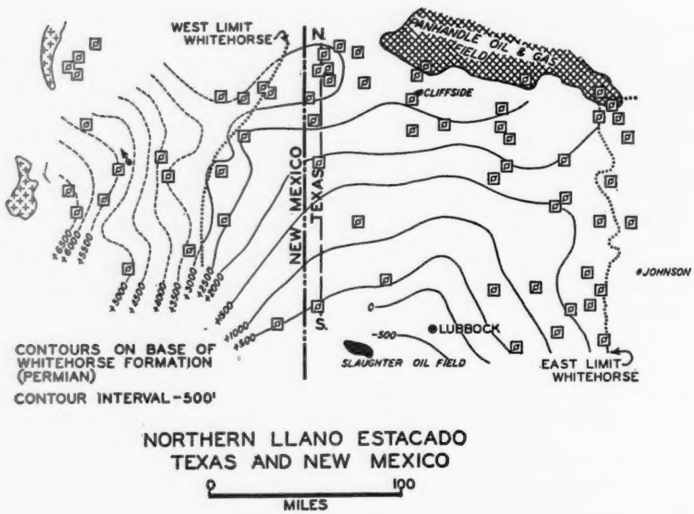

FIG. 1.—Map showing structure and general location of northern Llano Estacado region, west Texas and eastern New Mexico. Area described is contoured.

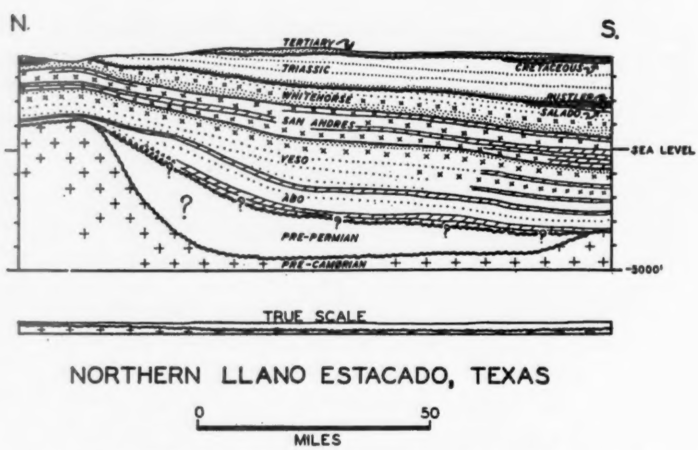

FIG. 2.—Generalized structure section across northern Llano Estacado. For line of section, see Figure 1.

Pennsylvanian, and Permian; the Panhandle field from the Ordovician, Pennsylvanian, and Permian; and the west-central and north Texas fields from the Ordovician, Mississippian, Pennsylvanian, and Permian.

Test wells along the east edge of the area give some information on the character of the pre-Permian rocks to be encountered in the basin. The Cambrian and Lower Ordovician Ellenburger rocks are predominantly dolomite. The Middle Ordovician Simpson group is limestone, shale, and sandstone. The Silurian and Devonian have not yet been found on the uplifts surrounding the basin but may be present in the basin. The Mississippian and Pennsylvanian should consist of limestone, sandstone, and shale with some granite wash in the upper Pennsylvanian near uplifts.

The possibilities for oil in this area are numerous and varied. Movements in the early Pennsylvanian created anticlines in the early Paleozoic rocks of the area. There should be numerous shoreline prospects in the late Pennsylvanian and early Permian. Coarse clastics of this age on the flanks of uplifts were overlapped by shales and dolomites. Unconformities are common in the area. One of the most profound in many places is that between the Ordovician and Mississippian.

The greatest hindrance to exploration has been the presence of large profitable oil provinces on three sides of the area, which can easily supply all the oil needed from this part of the country. Another unfavorable factor is that operators have been prone to test only the zones which produce in the nearest fields, instead of seeking new and deeper pays.

The best method of exploration at present seems to be persistent deep drilling to the basement rocks. Later, after some broad fundamental facts are learned, careful geological and geophysical studies will become more valuable.

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EDWARDS PLATEAU

This region comprises approximately 15,700 square miles. It is underlain by 1,000 to 12,000 feet—an estimated average of 1.6 miles—of marine sedimentary rocks, or a gross volume of about 26,000 cubic miles. The strata are known to include representatives of the Cambrian, Ordovician, Devonian, Mississippian, Pennsylvanian, Permian, and Cretaceous systems. The sedimentary section is divided by an important regional unconformity into two distinct portions, the Paleozoic and the Cretaceous, presenting entirely different exploration problems.

The Paleozoic section occurs in two facies associated with two tectonic elements. Bordering the Rio Grande is a segment of the Marathon-Ouachita mountain arc of pre-Permian folded rocks, and in the north are the southern parts of the Midland basin, the Eastern platform, and the Llano uplift, three of the principal tectonic elements of West Texas. The Marathon-Ouachita folded belt contains rocks which are metamorphosed to varying degrees. These rocks are overthrust northward upon more gently folded strata which represent the transition zone from the geosynclinal to the foreland facies. A deep test east of Del Rio (the Magnolia Petroleum Company's Wardlaw No. 1) passed from the basal Cretaceous through 1,600 feet of schist and marble of the overthrust sheet, and then entered slightly altered dolomite, probably of the Cambro-Ordovician Ellenburger group.[3] Oil accumulations may eventually be found in anticlines beneath and along the northern border of the overthrust; in stratigraphic traps in formations cut across by the overthrust; and in clastic members of the geosynclinal facies which wedge out toward the foreland on the north. Showings of gas were found in crystalline dolomite, probably Ellenburger, which underlies the Cretaceous in Joiner's Sellers No. 1, northwest of Del Rio. This test probably is near the border of the overthrust, as another test 2 miles east passed from the Cretaceous into metamorphic rocks.

North of the overthrust belt, the Paleozoic section consists of as much as 7,000 feet of shale and sandstone. Most of this section is probably Pennsylvanian in the southern and eastern part of the region and Permian in the northwestern. In a test west of the Pecos River 27 miles north of the Rio Grande (Milham's Bassett No. 1) part of the shale section is Middle Ordovician.[4] The thick Pennsylvanian succes-

[3] E. H. Sellards, "The Geology of Texas—Paleozoic Systems," *Texas. Univ. Bull. 3232* (1932), p. 189.

[4] Frank E. Lewis, "Position of San Andres Group, West Texas and New Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 1 (January, 1941), pp. 78–79.

sion in the south thins northward and changes from coarse clastics to fine clastics and limestones. The Permian rocks of the Midland basin, which overlie the Pennsylvanian with an important unconformity, are black, gray, and green shale with layers of limestone and fine-grained sandstone. The regional dip of the Cretaceous is southeastward and of the Permian northward, so that successively higher members of the Permian appear beneath the Cretaceous toward the north. The San Andres wedges in beneath the unconformity, and farther north the Whitehorse appears, overlapping the beveled edges of members of the San Andres. Possible wedge belts are in Pennsylvanian sands, which wedge out northward, and Permian sands, dolomites, and limestones, which show much lateral variation. The Pennsylvanian is unconformable on the older rocks, which certainly include Cambro-Ordovician dolomite and Middle Ordovician sandstone, shale, and limestone, lower Mississippian crinoidal limestone, and possibly other formations. Various sands in the Permian and Pennsylvanian of this region have shown oil and gas, in places in nearly commercial quantities. The lower Pennsylvanian produces oil in the Todd field just north of the region here discussed. The Cambro-Ordovician and Mississippian have shown free oil in parts of the region.

In the northeastern part of the Edwards Plateau the clastic facies of the Permian grades northeastward into massive limestone of the Eastern platform. The Page field produces oil and gas from a lower Pennsylvanian limestone on the western margin of the platform, and large but non-commercial showings of oil have been found in three different limestone members of the Pennsylvanian west of the Page field on the extreme eastern edge of the Midland basin. Sandstone members of the Pennsylvanian and basal Permian are very lenticular in this area and suggest the possibility of stratigraphic traps. The Permian is unconformable on the Pennsylvanian, and the Pennsylvanian truncates Mississippian and Cambro-Ordovician formations.

East of the Eastern platform the formations rise toward the Llano uplift. The lower Permian and successively lower Pennsylvanian formations are cut out by overlap of the Cretaceous. On the margins of the Llano uplift, the Pennsylvanian changes abruptly in thickness over local "highs," with accompanying lithologic changes. In two areas west of the south end of the Llano uplift, the Pennsylvanian has shown gas, and the Ellenburger has produced oil.

Exploration for oil in the Paleozoic rocks underlying the Edwards Plateau has been difficult because of the lack of conformity between the Cretaceous surface formations and the older rocks; the difficulty of correlating within the thick shale section; and the unsatisfactory

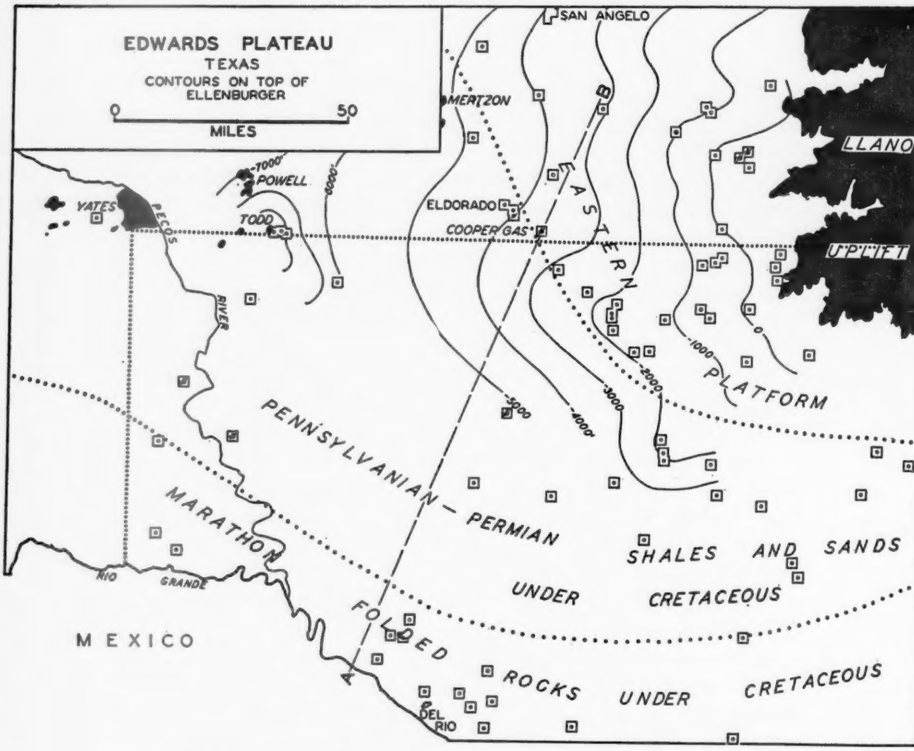

FIG. 3.—Map showing general features of Edwards Plateau region, Texas. Area described lies within black dotted line.

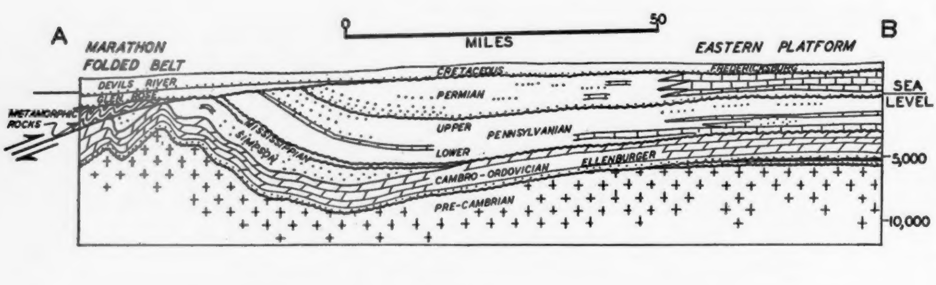

FIG. 4.—Generalized structure section across Edwards Plateau. See Figure 3 for line of section.

results that have been obtained by the use of ordinary geophysical methods. In the overthrust belt, the overthrust sheet does not conform structurally with the rocks below, contributing an additional hazard to exploration.

Within the Cretaceous system, gentle folds are superimposed on a regional southeast dip. The Cretaceous is thin and most of the section is exposed in the northern half of the region. The uppermost Trinity there overlies the Permian. Southward, successively lower members of the Trinity wedge in, and along the Rio Grande, 1,000 feet of Travis Peak sandstone and Glen Rose limestone are present below the top of the Trinity. Younger surface formations occur toward the south. Along the Rio Grande, the upper Washita Del Rio clay overlies about 1,300 feet of Devils River limestone, which rests on the thick Trinity section of that area. Northeast of Del Rio, small oil wells have been completed from lensing sand members of the Paluxy, at the top of the Trinity. The zone of the thick Trinity section in the Edwards Plateau is a northwestern extension of the Rio Grande embayment. Exploration for oil has appeared less likely to yield favorable results than farther southeast in the same structural province where a thick Tertiary section occurs, with a correspondingly greater number of objective horizons.

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TRANS-PECOS PROVINCE

WEST TEXAS AND SOUTHEAST NEW MEXICO

This province comprises approximately 45,000 square miles. It is underlain by 1,000 to 15,000 feet—an estimated average of 1.6 miles—of principally marine sedimentary rocks, or a gross volume of 75,000 cubic miles. The rocks include sedimentary representatives of every geologic system from the Cambrian to the Cretaceous, and volcanic and pyroclastic rocks of the early Tertiary.

The trans-Pecos province shows great diversity of structure, and

each of the chief tectonic subdivisions is related to a distinct facies of the sedimentary succession. Each tectonic subdivision is discussed separately.

In the southeast is the Marathon folded belt, composed of strongly folded and overthrust Cambrian, Ordovician, Devonian, and Pennsylvanian strata, consisting of about 55 per cent shale, 25 per cent sandstone, 15 per cent limestone, and 5 per cent chert and novaculite. The Pennsylvanian formations, which make up three-fourths of the total thickness, grade from coarse to fine clastics northwestward, furnishing possible wedge belts. The strata are strongly folded and are cut by both high-angle and flat overthrusts. Oil accumulations may be found in anticlines, in sands wedging out northward, and in beds sealed by faults. Unconformities occur at the base of and within the Pennsylvanian. Showings of oil in the Lower Ordovician limestone have been found in many wells drilled in the Marathon uplift. Except in the Marathon uplift and the Solitario, a small uplift on the southwest, the Paleozoic rocks are covered by the Cretaceous, which thickens from 200 feet in the north to 5,000 feet in the southern Big Bend. This thickening is due to the southward wedging-in of limestone and sandstone beds below the oldest Cretaceous beds present in the north and to the appearance southward of a thick Upper Cretaceous limestone and clastic section. Numerous large faults and many igneous intrusions occur in the southern Big Bend which make exploration for Cretaceous oil accumulations in wedge belts and fold and fault structures hazardous, and for Paleozoic oil even more difficult.

The Delaware basin in the northeastern part of the province is one of the chief tectonic features of the South Permian basin. The upper part of the Permian section in the Delaware basin contains as much as 4,000 feet of chiefly anhydrite and salt, with the Rustler dolomite and anhydrite at the top. Beneath is as much as 3,500 feet of sandstone and black shale of the Delaware Mountain group, part of which grades laterally into limestone and dolomite reefs on the margins of the Delaware basin and the remainder probably wedges out. Black limestones and shales occur in the lower part of the Permian section. Except for one well that penetrated the Pennsylvanian, the nature of the pre-Permian formations in the Delaware basin is known only by inference from the sections on the platforms bordering the basin, and the facies of these rocks in the basin may be quite different. Most tests drilled into the upper part of the Delaware sand have shown some high-gravity oil, but only one commercial accumulation has been found in the Delaware sand west of the Pecos River. The Toyah field in the basin west of the Pecos has produced from Quaternary sands, and to

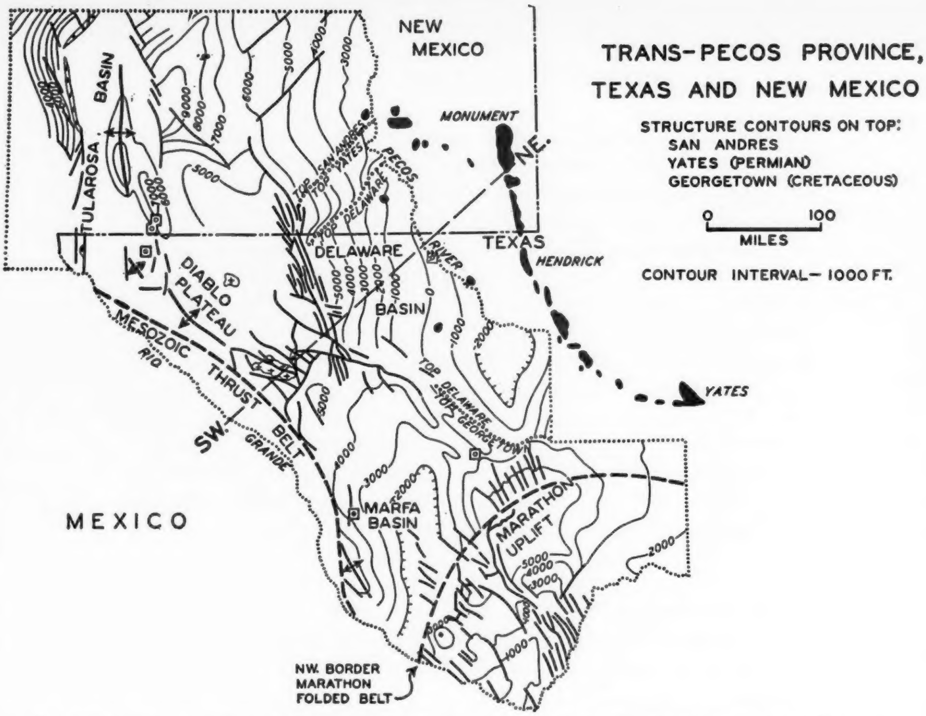

FIG. 5.—Map showing general features of trans-Pecos region, West Texas and southeastern New Mexico. Area described is within dotted line.

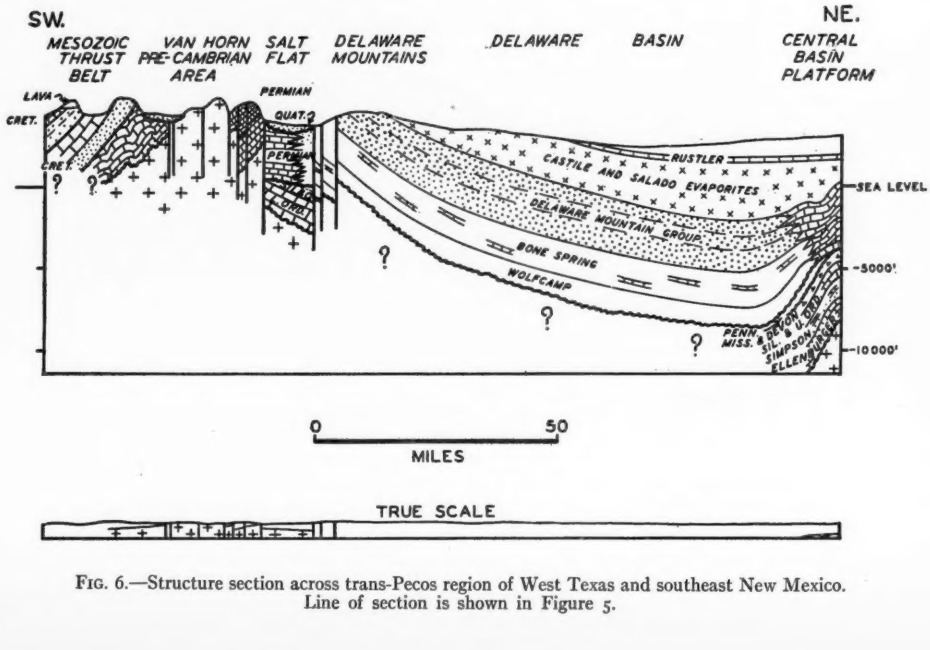

FIG. 6.—Structure section across trans-Pecos region of West Texas and southeast New Mexico. Line of section is shown in Figure 5.

a less extent from fractured Castile anhydrite. Unsuccessful attempts have been made to find oil reservoirs in the Delaware sand on the margin of the basin where it grades into reef limestone, but no persistent search has been made. The western part of the Delaware basin is downfaulted in Salt Flat, where favorable fault structures and limestone reefs may be concealed beneath the thick bolson fill.

South of the Delaware basin, and separated from it by a Permian positive axis, is the Marfa basin.[5] Little is known of this feature, but it appears to be comparable in size to the Delaware basin and to have a similar facies of Permian formations in it.[6] The surface in most of this area is mantled by thick volcanic rocks and a variable but not great thickness of Cretaceous. Scattered igneous intrusions occur.

North of the Marathon uplift and probably between the Delaware and Marfa basins a thick Permian section, dominantly limestone, overlies the Pennsylvanian and older rocks with profound unconformity. The Permian is at the surface north of the Marathon uplift and under cover of Cretaceous sedimentary and Tertiary volcanic rocks on the northwest. Limestone reefs grading into the clastic rocks of the basins may be found here, but much additional drilling will be necessary to outline the principal pre-Cretaceous tectonic and stratigraphic features.

West of the Delaware basin is the Diablo Plateau, where a shelf limestone facies of the Permian is developed. A great angular unconformity at the base of the Permian truncates the older rocks from the pre-Cambrian to the middle Pennsylvanian. A major positive axis, along which there has been recurrent movement from the pre-Cambrian to the Tertiary, appears to extend west-northwestward from Van Horn to several miles north of El Paso, but the axis was much obscured by faulting in Tertiary time. Important stratigraphic traps may be found on the flanks of this axis and possible parallel positive axes in the same region.

A plateau and mountain region in which Permian dolomites at the surface show numerous folds and faults occurs in the northern part of the province, between the Pecos River and the Tularosa basin. Little is known of the pre-Permian formations except in the western part of the region, but the unconformity at the base of the Permian may be expected to truncate at least the Pennsylvanian rocks.

[5] F. H. Lahee, "Contributions of Petroleum Geology to Pure Geology in the Southern Midcontinent Area," *Bull. Geol. Soc. America*, Vol. 43 (December, 1932), pp. 953–64, Fig. 2.

[6] John W. Skinner, "Upper Paleozoic Section of Chinati Mountains, Presidio County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 1 (January, 1940), pp. 180–88.

The Tularosa basin is a deep graben with several known anticlines in the Permian, and containing some igneous intrusions. All Paleozoic systems probably occur beneath the generally thick alluvial cover.[7]

Along the Rio Grande south of El Paso is found a belt of strongly folded and overthrust Mesozoic rocks, which are the northeast front of late Cretaceous and early Tertiary folds that form a broad mountain area in northern Mexico and occur only in a narrow zone in Texas. Several tests have drilled through the overthrust into underlying Paleozoic rocks, but in most of the Mesozoic thrust belt, the nature of the Paleozoic rocks is unknown. The Cretaceous section of the Diablo Plateau is thin, and begins in the middle Trinity. In the ranges bordering the Rio Grande, successively older formations—at least 4,000 feet thick—wedge in below the middle Trinity, and a continuous sequence down into the upper Jurassic is probably present, though the succession is broken by thrust faults.[8] The margin of the transgressing deposits has a clastic facies, and the lower part of the Cretaceous is a thick clastic formation. One test drilled at the east edge of the Cretaceous folded belt in western Marfa basin (Brite's Fee No. 4) encountered free oil in the Buda limestone (Lower Cretaceous). An alluvium-filled structural basin at Presidio is probably underlain by a thick sequence of Mesozoic rocks which may be expected to wedge out northeastward.

Exploration for oil in the trans-Pecos region has been retarded principally because of the complexity of structure and lack of conformity between the surficial rocks and the strata most likely to be reservoirs. In addition, the Big Bend region is remote from present markets. The Diablo Plateau, however, is crossed by two pipe lines and does not have this disadvantage. Few tests drilled in the trans-Pecos province have penetrated as much as three-fourths of the sedimentary section.

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[7] N. H. Darton, " 'Red Beds' and Associated Formations in New Mexico," *U. S. Geol. Survey Bull. 794* (1928), pp. 216–19.

[8] W. S. Adkins, "The Geology of Texas. Vol. 1, Stratigraphy. The Mesozoic Systems in Texas," *Univ. Texas Bull. 3232* (1932), Fig. 14, p. 289, and Fig. 15, p. 292.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 25, NO. 8 (AUGUST, 1941), PP. 1539-1562, 16 FIGS.

POSSIBLE FUTURE OIL PROVINCES OF EASTERN CANADA

GEOLOGICAL SURVEY OF CANADA
Ottawa, Ontario
QUEBEC BUREAU OF MINES
Quebec, Quebec
NEWFOUNDLAND GEOLOGICAL SURVEY
St. Johns, Newfoundland

HUDSON BAY AND JAMES BAY REGION

A low coastal plain borders James Bay on the south and west and extends northwest to the Churchill River and beyond. It has a width of 75 to 100 miles in the basin of the Moose River where its seaward slope is about $3\frac{1}{2}$ feet per mile and its width is still greater in the basin of the Albany River. The limits of this coastal plain are approximately those of the Paleozoic rocks particularly in the south and southwest. The strata underlying this coastal plain vary in age from Ordovician to Devonian with small areas covered by Lower Cretaceous beds in the Moose River region. Ordovician, Silurian, and Devonian strata are all known to rest directly on the pre-Cambrian in different places and in much of the region south of James Bay covered by Devonian and Cretaceous beds, the Ordovician and Silurian appear to be absent. No Devonian rocks have been reported in the region north of the basin of the Albany River.

The Paleozoic sediments are chiefly of marine origin and are composed largely of limestone and shale with small amounts of gypsum and sandstone.

In general the strata are nearly flat-lying with gentle dips toward the north and east toward James Bay and Hudson Bay. For example, along Nelson River and its tributaries the strata have a general dip toward the east or downstream a little steeper than the grade of the stream. Gentle undulations in the strata are also common and low arches 10 to 50 feet high are not rare. An anticlinal fold crosses Winisk River Valley about 5 miles above the mouth of its tributary, the Shummattawa. At this place the base of the Silurian is exposed and is seen to rest unconformably on quartzites of pre-Cambrian age.

In the Moose River Basin the strata dip north and northeast at about the same rate as the fall of the river; hence, the same horizon occurs at many exposures along the rivers. Broad undulations, however, are present in some places. One prominent anticlinal fold occurs in the lower part of Long Rapids on Abitibi River while farther downstream the Cretaceous lignite basin has been preserved in a broad syn-

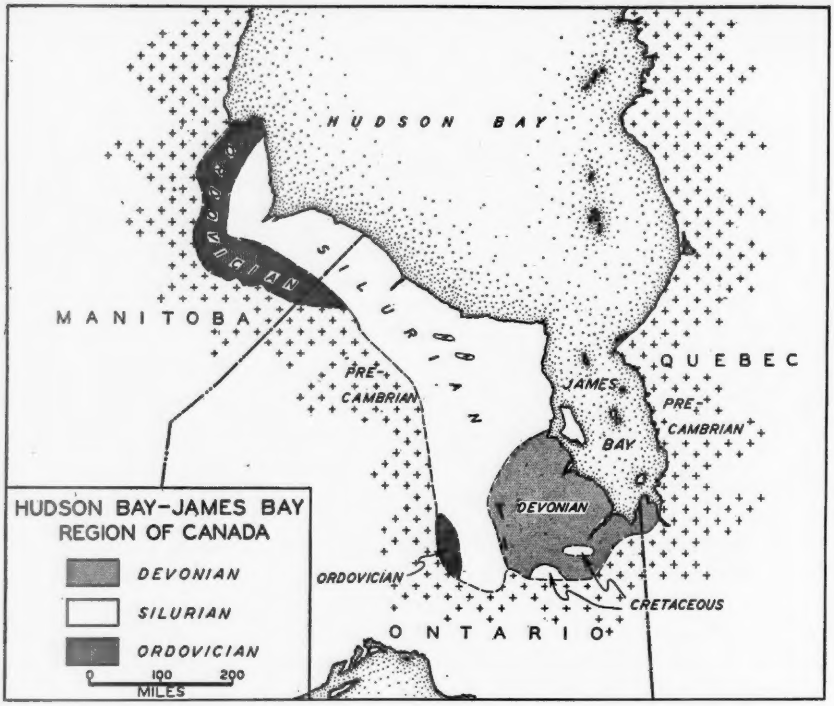

FIG. 1.—Map showing general features of Hudson Bay—James Bay region.

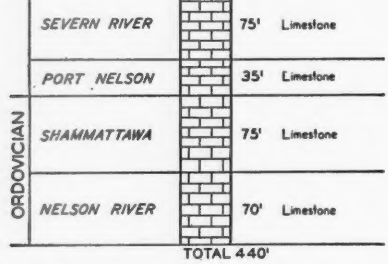

FIG. 2.—Severn River geologic section on southwest side of Hudson Bay, Canada.

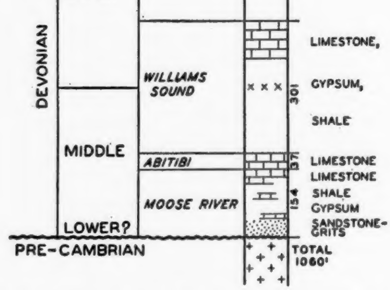

FIG. 3.—Moose River basin geologic section on south end of James Bay, Canada.

cline. The diamond-drill hole which yielded the geological section was located near the axis of this syncline.

No seepages of oil or gas have ever been discovered in this region and the deep diamond-drill test did not encounter any evidence of oil or gas. If we consider only regions where the thickness of sediments above the basement complex is greater than 1,000 feet, it appears that only a very small part of the James Bay region can qualify and the Hudson Bay region on the northwest not at all. The general lack of development in this region is due to its inaccessibility and difficulty of transport, also to the thick cover of glacial and marine Pleistocene deposits and the general lack of outcrops of bed rock except along some of the main streams.

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ONTARIO

EASTERN ONTARIO

The area is bounded on the north and south by the Canadian shield and the International Boundary, on the west by the Frontenac (pre-Cambrian) axis, and on the east by the Ontario-Quebec boundary. It roughly covers 5,000 square miles. It consists of a basin in the pre-Cambrian complex filled with marine Ordovician sediments having a maximum thickness of 2,100 feet, and eroded to a few inches along the west, north, and east margins where the basal sandstone rests on the pre-Cambrian.

Three unconformities are evident, one between the pre-Cambrian and basal Paleozoic sandstone, one between the Beekmantown and Chazy sediments, and a less evident one between the Chazy and Black River-Trenton sediments. The contact between the Black River-Trenton and Collingwood-Gloucester, and between the Collingwood-Gloucester and the Lorraine-Dundas is nowhere exposed.

The main structural feature is a large downfaulted block, cut off by fault zones on the north, west, and south. It is so tilted that its maximum depth is at the west and south, and its eastern extremity inclines upward almost regaining its normal monoclinal position

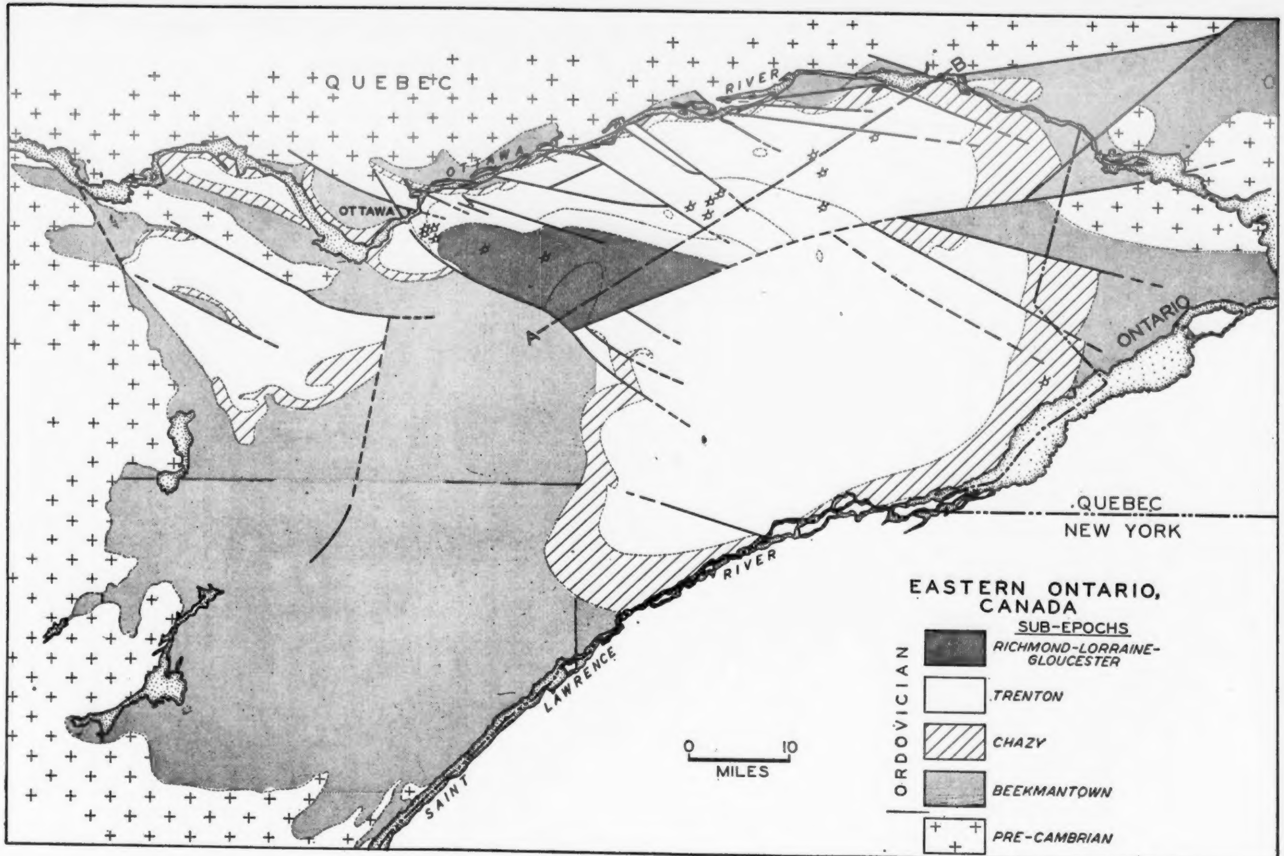

FIG. 4.—Geologic map of eastern part of Ontario, Canada.

FIG. 4.—Geologic map of eastern part of Ontario, Canada.

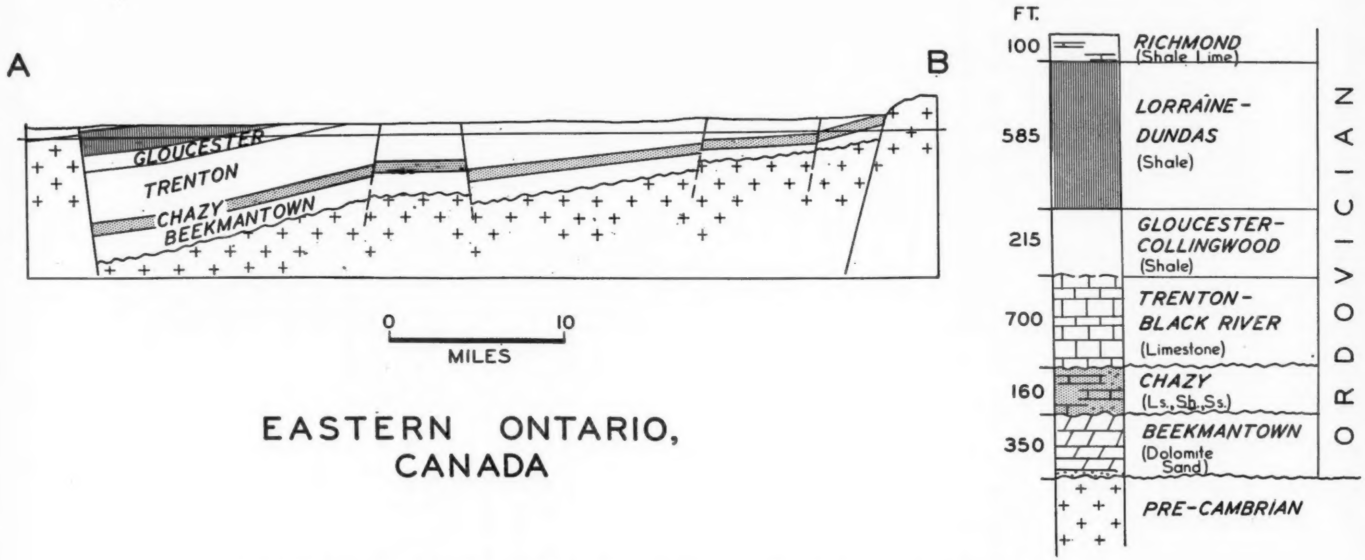

FIG. 5.—Generalized structure section and geologic column in Ontario. Line of section shown in Figure 4.

against the pre-Cambrian. The block is semi-oblong with its greatest dimension northeast-southwest.

Practically all the oil or gas reported has come from the west and south of the block, from the younger Ordovician beds preserved by its downward tilt, and again from about the center of the block where a further downwarping interrupts the regular eastward uptilting. In the rest of this Paleozoic basin all the younger beds have been eroded except in a limited area directly south and opposite the central downwarping within the block.

Gas has been reported from twelve wells. Of these eleven are drilled in the downfaulted block. The source of the gas is the black bituminous shale of Collingwood-Gloucester age and the upper half of the Black River-Trenton beds. One well just south of Ottawa produced a flow for 10 days, another near the center of the block produced sufficient to supply a private house. The gas appears to be in pockets and has nowhere been found in commercial quantities.

Gas was reported east of Cornwall from one well penetrating Chazy rocks. A large number of other wells have penetrated beneath the Chazy rocks but no other has recorded gas from this horizon, though near Plantagenet a small oil discoloration was noticed in a spring at the Beekmantown-Chazy contact.

CENTRAL ONTARIO

The area lies between the 76°00′ and 79°00′ parallels of longitude. It is bounded on the north and south by the pre-Cambrian shield and Lake Ontario, respectively, and occupies roughly 7,800 square miles. The Paleozoic basin is cut off on the east by the western margin of the Frontenac axis connecting the Canadian shield with the Adirondacks.

The area is an extension of the larger basin of the Western Ontario Peninsula which dips gradually southwest, exposing progressively older sediments on the north and east. The Paleozoic marine sediments of the part under discussion lie directly on the pre-Cambrian base and are of Middle Ordovician age except for a few small outliers of sandstone in the extreme east, remnants of the earliest Ordovician or Upper Cambrian sandstone occurring east of the Frontenac axis.

The sediments have a maximum thickness of approximately 1,000 feet. Except for the scattered sandstone outliers on the east and a small region of black bituminous shale of Gloucester age in the southwest, the deposits consist of thick beds of limestone with a few feet of basal arkose, and are of Trenton-Black River age. The limestones attain their maximum thickness of nearly 1,000 feet in the Picton area. They

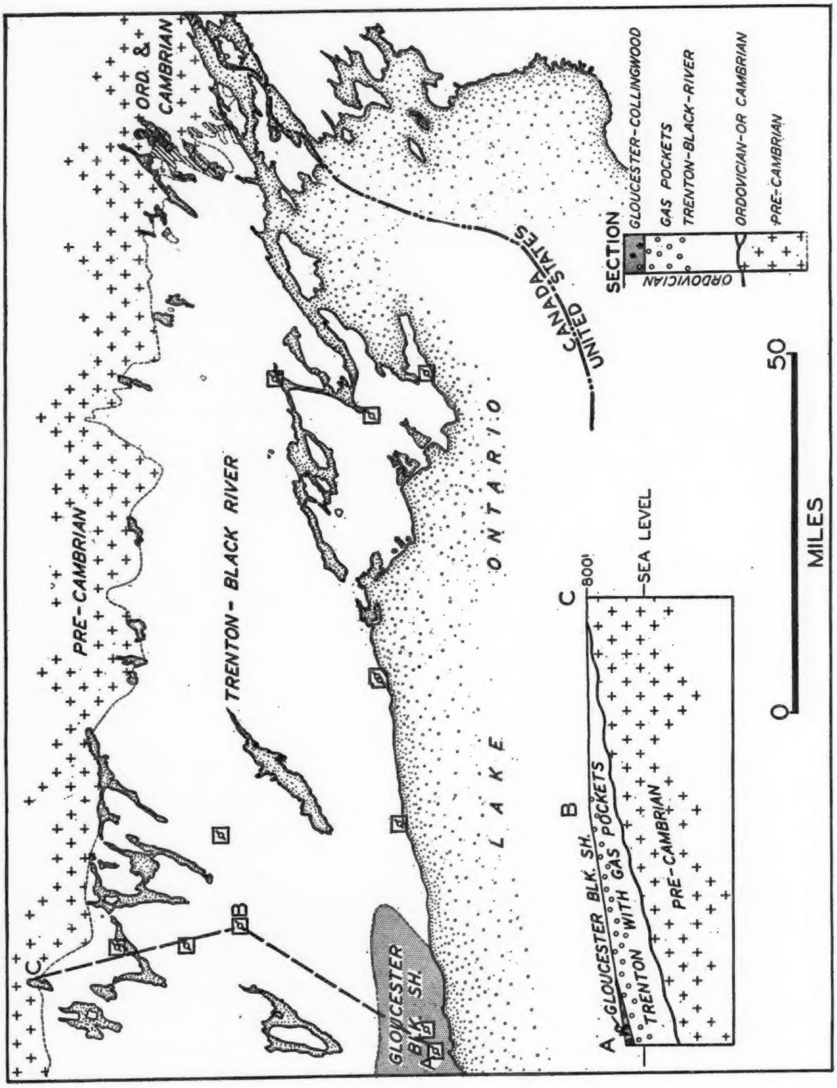

FIG. 6.—Map showing general features in central Ontario.

become gradually thinner toward the west, and more abruptly thinner toward the east.

In the extreme east there is an unconformity between the pre-Cambrian and the basal sandstone outliers, and another between the basal sandstone and the Middle Ordovician sediments, but over the major part of the area there is one unconformity between the pre-Cambrian complex and the Middle Ordovician deposits.

As far as known the structure of the sediments is simple.

The gas reported comes in the main from wells near the lake shore. The source is the black bituminous shale of Gloucester age and the upper part of the Trenton limestone. Practically all reported occurrences of gas have come from approximately 400 feet or more above the arkose. In two cases, however, near Lindsay and Peterborough, gas occurs at approximately 250 and 100 feet above the base. There are indications, not yet studied, that the later Trenton deposits overlap the older beds in the northwestern part of the area. This might mean that in these two isolated cases, like the others, the gas occurs in the upper Trenton beds. In all cases the gas appears to occur in limited pockets and has never been found in commercial quantities.

ONTARIO PENINSULA

This area lies between Lakes Huron, Ontario, and Erie and forms the western part of the St. Lawrence physiographic province stretching southward from the Canadian shield. It is divided into an eastern lowland and western highland by the Niagara escarpment which presents an abrupt western rise of 250 to 300 feet. The lowland rises gently northward from the level of Lake Ontario (246 feet) to the level of Georgian Bay (578 feet) but altitudes up to 1,300 feet occur between these points. The highland west of the escarpment rises northward from Lake Erie (572 feet) attaining a maximum altitude of about 1,700 feet in the district southwest of Collingwood. The surface is rolling but with low relief.

The entire area has been glaciated and is covered with a mantle of glacial drift. The drift varies from a few feet to more than 500 feet in thickness and produces a surface topography that in no way expresses the structure of the underlying bed rock.

The area is underlain by Paleozoic sedimentary rocks. Ordovician strata underlie the whole area and are overlain by glacial deposits throughout the lowland region. They attain a maximum thickness of about 2,873 feet. Silurian rocks form the Niagara escarpment and underlie all the upland area to the west where they attain a thickness

of about 2,248 feet. Devonian rocks occupy the southwest part of the area and reach a thickness of about 1,320 feet.

The general structure is indicated by the areal distribution of the rocks. The strata have a gentle dip south and southwest away from the Canadian shield at angles between 25 and 40 feet a mile. This regional structure carries locally small rolls, domes, and anticlines that are for

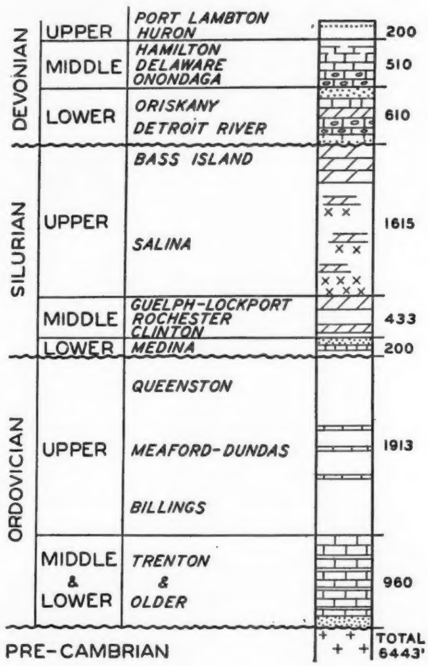

FIG. 7.—Generalized geologic column of Ontario Peninsula.

the most part detectable only from detailed study of drilling records. Porosity variation and sedimentary irregularity are evident at some localities. Regional disconformities are known at several horizons, for example, at the top of the Ordovician, at the top of the Silurian, and within the Devonian system. The attitude of the rocks both above and below the breaks is essentially the same wherever the unconformities have been observed.

At present commercial production is confined to the region south

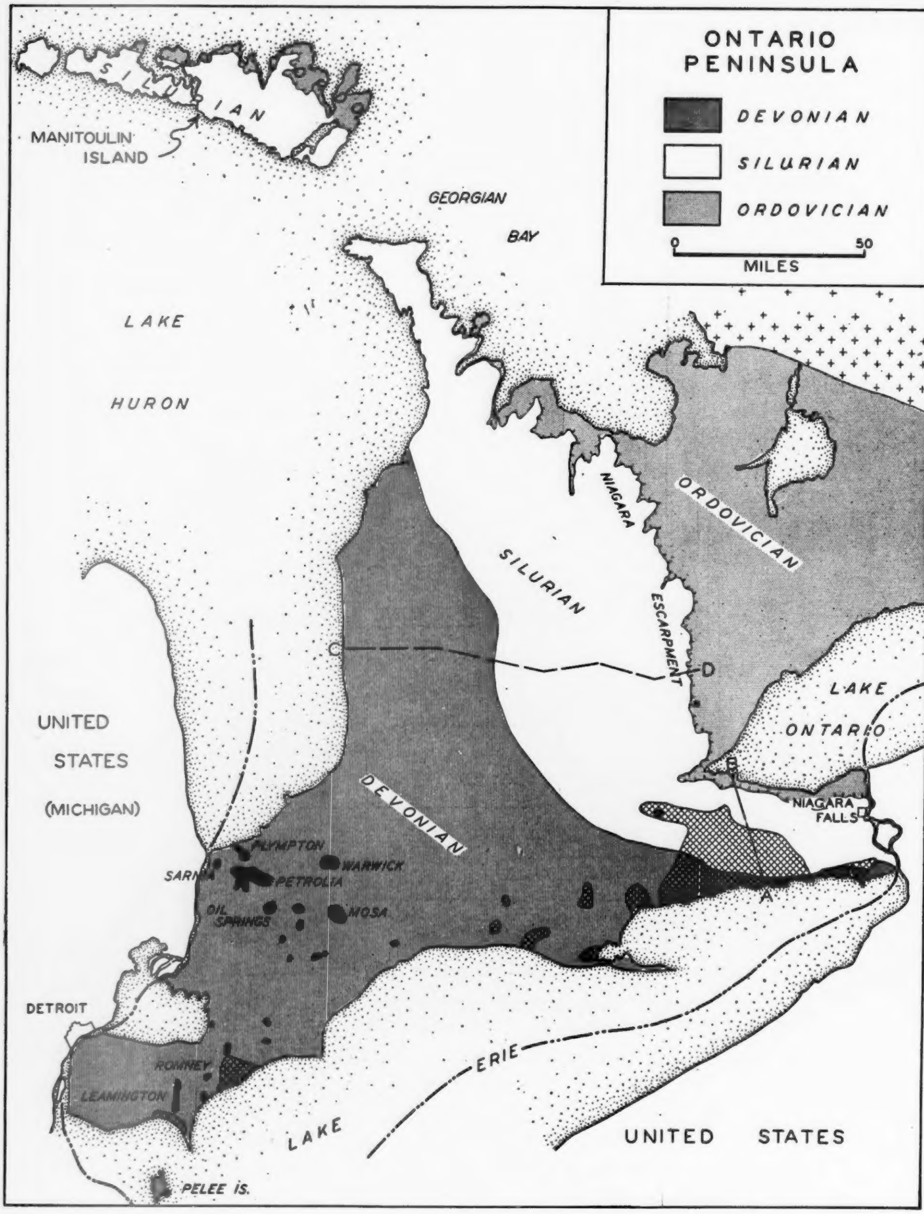

FIG. 8.—Map showing general features of Ontario Peninsula.

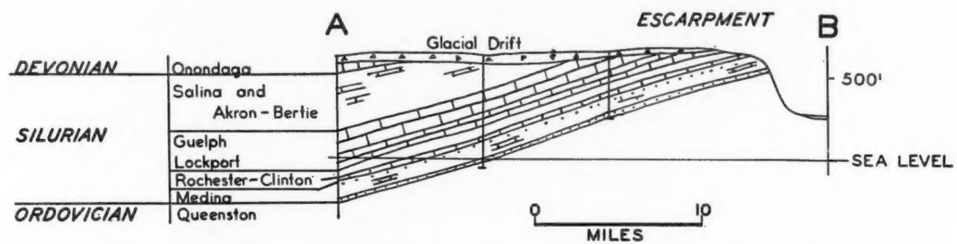

FIG. 9.—Generalized structure section across Ontario Peninsula along line AB shown in Figure 7.

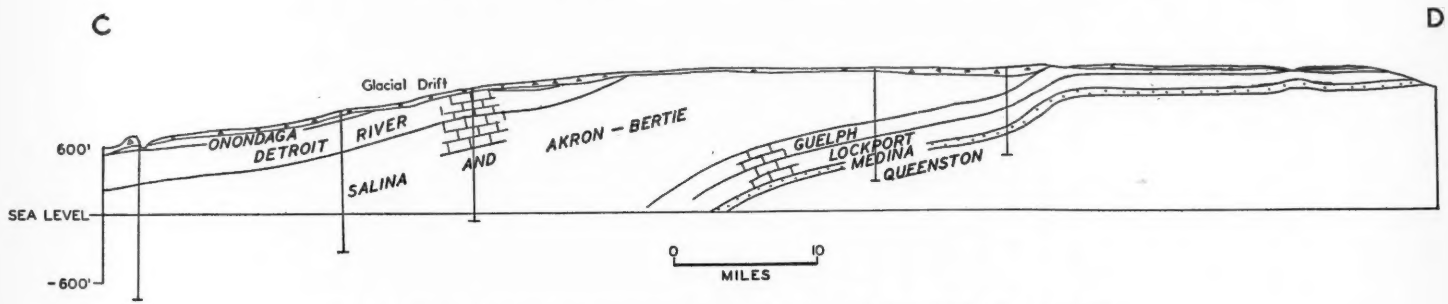

FIG. 10.—Generalized structure section across Ontario Peninsula along line CD shown in Figure 7.

of a line joining Hamilton and Sarnia. Only gas is produced in the Niagara peninsula whereas west of London the major part of production is oil. Practically the entire oil production is from Middle Devonian limestones (Delaware-Onondaga) although in Dover West field a small yield is from the Ordovician (Trenton) and in the Onondaga field a small quantity comes from the base of the Silurian (Whirlpool sandstone). The chief gas-producing formations are in Silurian rocks (Guelph dolomite, Clinton limestone, Grimsby sandstone, Whirlpool sandstone), with the Trenton yielding gas in Dover West township.

Several localities within the general producing region are considered as worthy of prospecting and during the last 3 years one oil field and two gas fields have been discovered.

Widely scattered test drilling has been done throughout the area north of the Hamilton-Sarnia line. Shows of both gas and oil have been obtained at several places but nothing commercial has as yet been discovered. Parts of this region may be considered as unfavorable, for example, the lowland district in the vicinity of Collingwood. Here, the sediments are thin and the Trenton, which holds the only prospective producing formation, crops out nearby. Also unfavorable is much of the region west of the escarpment where Silurian rocks immediately underlie the drift and most of the known Silurian producing formations crop out along the escarpment.

No oil seepages are known except where fields now exist. More than 10,000 oil and gas wells have been drilled in the Ontario peninsula; the majority of these are in the present producing region.

The prevalence of glacial drift and consequent scarcity of outcrops renders very difficult detailed structural studies based on surface observations.

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MARITIME PROVINCES OF CANADA

NOVA SCOTIA AND NEW BRUNSWICK

A good general picture of the geology of New Brunswick and Nova Scotia is afforded by the physiographic features. This is so because the major upland tracts of the region are underlain by metamorphosed sediments and igneous rocks (Fig. 11). Middle Devonian orogeny and intrusions of granite were significant and widespread events in the tectonic history of the maritime provinces. Devonian rocks of later age than the orogeny are absent except in a few small restricted areas in New Brunswick.

The lowlands are underlain by unaltered sediments of Carboniferous age with the exception of the Minas basin which is covered by non-marine Triassic sediments. The Carboniferous strata are therefore the only ones that require consideration in evaluating oil possibilities of the maritime provinces because the sediments of pre-Carboniferous age are so greatly altered. The most noticeable features of the Carboniferous strata are the dominance of non-marine (?) sediments and the remarkable thickness of individual formations (Fig. 12).

The Carboniferous strata have been folded and faulted, the general trend of the folds being northeast-southwest. Details of structure are difficult to unravel because of the local character of much of the strata and the general lack of key beds. In New Brunswick, the Mississippian strata are much folded and faulted beneath the gently folded overlapping upper Pennsylvanian strata. In Nova Scotia, however, lower Pennsylvanian strata are conformable with the Mississippian beds and were folded prior to the deposition of the middle Pennsylvanian.

In New Brunswick, indications of petroleum occur as gas and oil seepages, asphaltic residues, and albertite, a solidified asphalt. All these are closely associated with the Albert formation in the upper part of the Horton series. This formation contains numerous beds of oil shale and is considered the source of accumulations of oil. The best known development of the Albert formation occurs in the northeast half of the elongate folded and faulted basin of Mississippian strata that extends from Moncton to within a few miles of the city of St. John. Northeast of Moncton, strata of Pennsylvanian age blanket the entire region, and the limits of the Albert formation will only be known by drilling.

The only petroleum producing field in the Maritime provinces is the Stoney Creek field about 9 miles south of Moncton. The productive area is about 3 miles long by about 1½ miles wide. The production occurs on the north limb of a synclinal basin and comes from sandstone

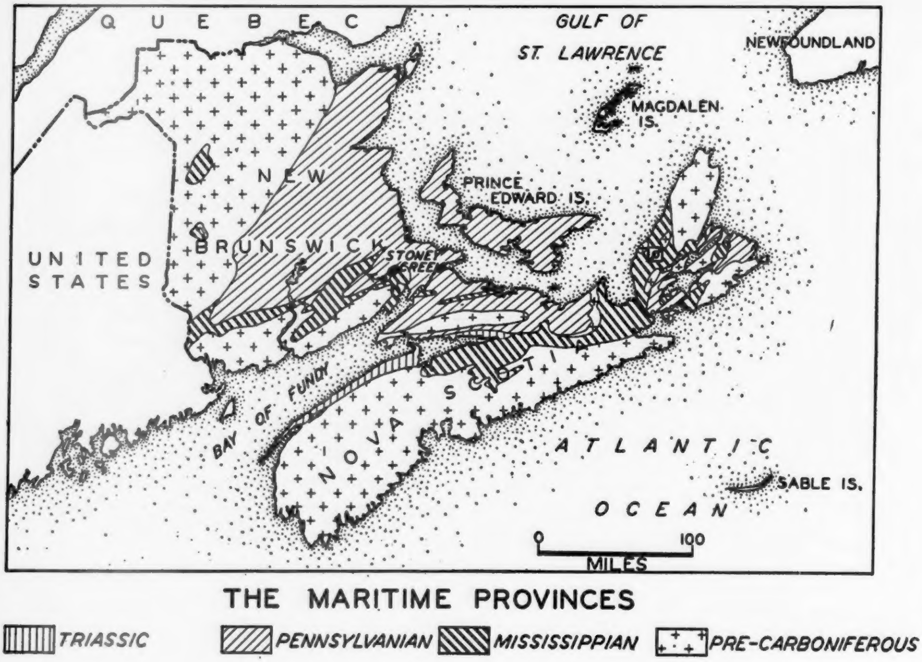

FIG. 11.—Map showing general features of Maritime provinces.

	PERMIAN OR UPPER	*PRINCE EDWARD IS. STRATA*	UNKNOWN	SANDSTONE, SHALE, COAL (NON-MARINE)
PENNSYLVANIAN	UPPER	*PICTOU SERIES*	7,000'+	
	MIDDLE	*CUMBERLAND SERIES*	7,000'+	
	LOWER	*RIVERSDALE SERIES*	6,000'+	
		CANSO SERIES	3,000'+	SANDSTONE, SHALE (NON-MARINE)
MISSISSIPPIAN	UPPER	*WINDSOR SERIES*	3,000'+	SANDSTONE, SHALE, CONGLOMERATES, EVAPORITES (NON-MARINE)
	LOWER	*HORTON SERIES*	8,000'+	SANDSTONE, SHALE, CONGLOMERATE, LIMESTONE, OIL-SHALE, COAL (NON-MARINE)
			TOTAL 34,000'+	

FIG. 12.—Generalized geologic column in Maritime provinces of eastern Canada.

lenses in dark gray shales of the Albert formation. The wells vary in depth from 1,500 to 3,000 feet. In the 30-year period from 1909 to 1939 this field has yielded $17\frac{1}{2}$ billion cubic feet of gas and 240,000 barrels of oil.

It is possible that other gas and oil fields of the Stoney Creek type may be found in basins occupied by Mississippian sediments in New Brunswick, but where these are covered by Pennsylvanian strata, for example, between Moncton and Northumberland Strait, some type of subsurface prospecting will be necessary to find them.

Attempts have been made to exploit the oil shales of the Albert formation 6 to 8 miles south of the Stoney Creek field but they are interbedded with much barren strata. In this same vicinity a vein of albertite (a solid hydrocarbon) 16 feet wide was discovered. This was a true fissure vein cutting the strata and was mined over a length of half a mile and to a maximum depth of 1,100 feet. In all, 200,000 tons of albertite was mined.

In Nova Scotia, near New Glasgow, black shales from which oil can be distilled occur with coal-bearing strata of the Pictou series. The richest of these beds is torbanite.

In the vicinity of Lake Ainslie, Inverness County, Nova Scotia, petroleum residues occur in a brown sandstone in the upper part of the Horton series, and globules of oil have been observed rising to the surface of the lake. Deep tests have been drilled at various times but no commercial production has been obtained.

It is probable that the main factors that have deterred more active prospecting in the Maritime provinces, are the prevalence and great thickness of non-marine (?) sediments and the lack of surface indications of oil and gas in the form of live seepages.

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PRINCE EDWARD ISLAND

Prince Edward Island has everywhere a low and undulating surface. The underlying strata consist almost entirely of soft red sandstones and arenaceous shales of late Pennsylvanian or Permian age. Over the greater part of the island the beds dip northward at angles of less than 5°, with, however, broad undulations on the south which probably cause the same beds to be repeated in sections on opposite sides of the island.

Five exploratory wells each about 2,000 feet deep were financed by the Government. These wells were drilled to obtain general geological information as well as to explore for coal, oil, and gas. Four of the wells were located on the eastern part of the island and one on the western part. Later, private interests drilled a well 5,970 feet deep on Governor's Island in an attempt to find oil. Nothing of economic value was discovered in any of the drill holes. In all these wells the strata encountered were a monotonous succession of red sandstones and shales. These beds are thought to be upper Pennsylvanian in age and of fresh-water origin.

The main factors that have probably discouraged more active exploration are the lack of knowledge regarding the more deeply buried rocks and the continental character of the beds encountered in drilling. No seepages of oil or gas are known.

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MAGDALEN ISLANDS

The larger Magdalen Islands in the Gulf of St. Lawrence show

central hilly parts surrounded by more or less flat belts. The highest elevation is 559 feet while the elevation of the surrounding plains is for the most part less than 100 feet above the sea. The oldest rocks occur in the central hilly part and consist of sediments and interbedded volcanic rocks of upper Mississippian (Windsor) age. The sediments are composed of limestone, gypsum, and gray sandstone and the volcanics are largely breccias and tuffs of unknown thickness. These rocks were folded and eroded and, around the resulting hills, beds of red sandstone were deposited. This red sandstone is thought to be of Pennsylvanian age and of fresh-water origin. It is at least 300 feet thick, covers three-fourths of the island areas, and is nearly flat. The unconformable relations between this sandstone and the underlying Windsor series can be seen at many places in coast sections.

No seepages of oil or gas are known on these islands and the presence of much volcanic material is an unfavorable factor.

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QUEBEC[1]

I. W. JONES

In the province of Quebec, there are two regions that may sometime be producers of oil: the Gaspé Peninsula and the St. Lawrence Lowlands.

GASPÉ PENINSULA

This peninsula is bordered on its north and south sides by belts underlain mainly by shales and limestones of Ordovician age. Through the center of the peninsula, for its entire length of about 150 miles and along the general trend and strike of the structures and formations, there is a belt 20 to 35 miles wide of Devonian limestones, shales, and sandstones with Silurian limestones, shales, and conglomerates showing in narrow bands and isolated areas. Intrusive and extrusive igneous rocks of different ages are found in various parts.

The older Paleozoic rocks of the northern and southern belts are highly folded, squeezed, and faulted. The Silurian and Devonian strata lie in a series of anticlinal and synclinal folds of medium intensity, and they are cut by faults of varying importance. Unconformable relations apparently exist between the Ordovician and Silurian, and there is possibly, in some places, a disconformity between the Silurian and Devonian.

[1] Published by permission of the Deputy Minister, Department of Mines, Quebec.

Bituminous shales are known in the Ordovician. Oil-soaked limestones (fossil-reefs and highly fossiliferous beds) crop out in the Silurian areas. Oil seepages and limestones with petroliferous odor are found in the Lower Devonian. Bituminous shales and oil seepages are known in Middle Devonian strata (mostly shale and sandstone). Oil of excellent quality, but not in commercial quantity, has been obtained in wells and still flows from some of them after 40 to 80 years.

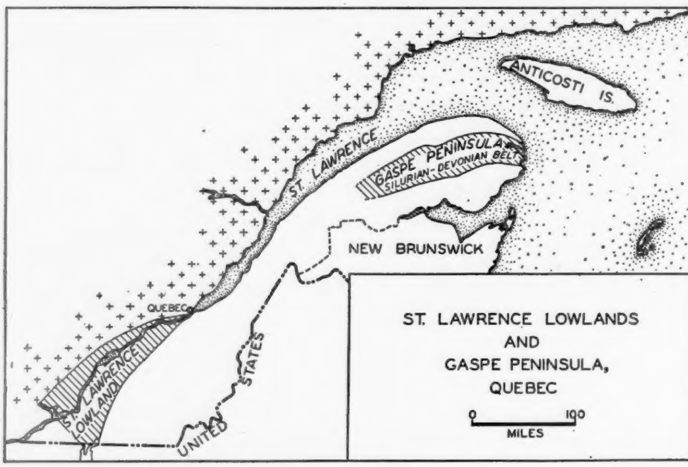

FIG. 13.—Map showing location of St. Lawrence Lowlands and the Gaspé Peninsula of Quebec. Areas described are cross-hatched.

Fifty-nine holes have been drilled in eastern Gaspé, mostly in the period from 1860 to 1903. Most of them were located in synclines or well down the flanks of anticlinal folds; the few that were on anticlines penetrated only strata that were "open" on the structures and did not reach to certain possibly oil-bearing formations. The deepest of these earlier holes was 3,600 feet. In an unsuccessful attempt in 1939–1940, a depth of 5,995 feet was attained at a location well up an anticlinal flank; this hole, drilled in Lower Devonian strata, probably entered the Silurian but did not reach the possibly oil-soaked zone of this formation which is estimated to be 1,000 to 1,200 feet deeper. The Ordovician might have been reached, if drilling had continued, at still an additional depth of about 800 feet.

In eastern Gaspé there are favorable structures that have not been tested; certain horizons may be tested in one locality and certain others in another, and in some localities two or more possibilities may be tested in the same project. The major uncertain factor is that of

porosity; drilling is probably the only satisfactory method of determining whether there are conditions of porosity favorable to the accumulation of the oil that is known to exist. Should oil be found in commercial quantity in this eastern part of Gaspé, search would undoubtedly extend westward on other structures throughout the central belt of the peninsula and possibly farther west to the less known region west of the Matapedia Valley. In this valley, petroliferous fossil-bearing Silurian limestone has been found under conditions similar to those existing some 150 miles away in eastern Gaspé.

ST. LAWRENCE LOWLANDS

The St. Lawrence lowlands extend along both sides of the river of this name, approximately from Montreal to Quebec. They are bounded on the north by the pre-Cambrian rocks of the Laurentian hills, and on the south by the much disturbed belt of the Appalachian Mountain system.

The rocks of the lowlands range mainly from Lower to Upper Ordovician, with the Cambrian and possibly the Silurian being represented in some places. A total of about 5,000 feet of Ordovician strata is indicated.

North of the St. Lawrence the beds are generally flat or gently dipping. South of the river the structure is not the comparatively simple synclinal basin as was once believed; in part, it is an area of complex folding and faulting.

Gas has been found at the base of the surface clay and at some lower horizons, and some of the Trenton (Middle Ordovician) limestones are known to be petroliferous.

While no commercial success has been attained in the several attempts to find oil and gas in this region, it is considered that the possibilities have not been exhausted.

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NEWFOUNDLAND[2]

HELGI JOHNSON

Two areas in the lowland of western Newfoundland in the vicinity of Port au Port on the St. George Peninsula and at Parsons Pond have long been known to contain petroleum, but several attempts at drilling and recovering oil have met with scant success. In addition, oil shales and seepages of bitumen are known to occur in Carboniferous sediments near Conche on the northeast coast and at Grand Lake in the central basin, while bituminous limestones crop out along the shores of Bay St. George (Fig. 14).

The western lowland is underlain chiefly by Cambrian and Ordovician sediments having an aggregate thickness of 10,000 to 12,000 feet. Pre-Cambrian crystalline rocks have been pushed northwestward, disturbing and over-riding them. Cambrian sediments predominate in the north where they rest unconformably on the pre-Cambrian and attain a maximum thickness of 1,200 feet. They consist of quartzites, shales, and dolomitic limestones and may be eliminated as a possible reservoir for oil. In the central and southern parts of the area, for example, Port au Port, small fault splinters and erosional remnants of similar rocks appear along with a thick Ordovician succession. The Ordovician rocks of the lowland are divisible into two principal facies: a limestone-dolomite facies, which is generally flat or only gently crumpled, overlying the Cambrian in the north (Fig. 15) and a shale-sandstone-limestone facies in the central and southern parts of the area. The beds of the latter are greatly disturbed, stand at high angles, and in many places are vertical and even overturned (Fig. 16). Thrust-faulting involving two orogenic movements has produced much repetition of the strata and, in some places, has intermingled the limestone and shale succession. Faunal studies show these beds, as well as the limestones, to be of Lower Ordovician (Canadian) and Middle Ordovician (Chazyan) age and, furthermore, the two facies to be age equivalents. It seems obvious, therefore, that they owe their present juxtaposition to fault movements.

The presence of oil in the western lowland is confined to this highly disturbed zone and is associated only with the shales and intercalated fractured limestones of the shale facies. Whether or not the oil origi-

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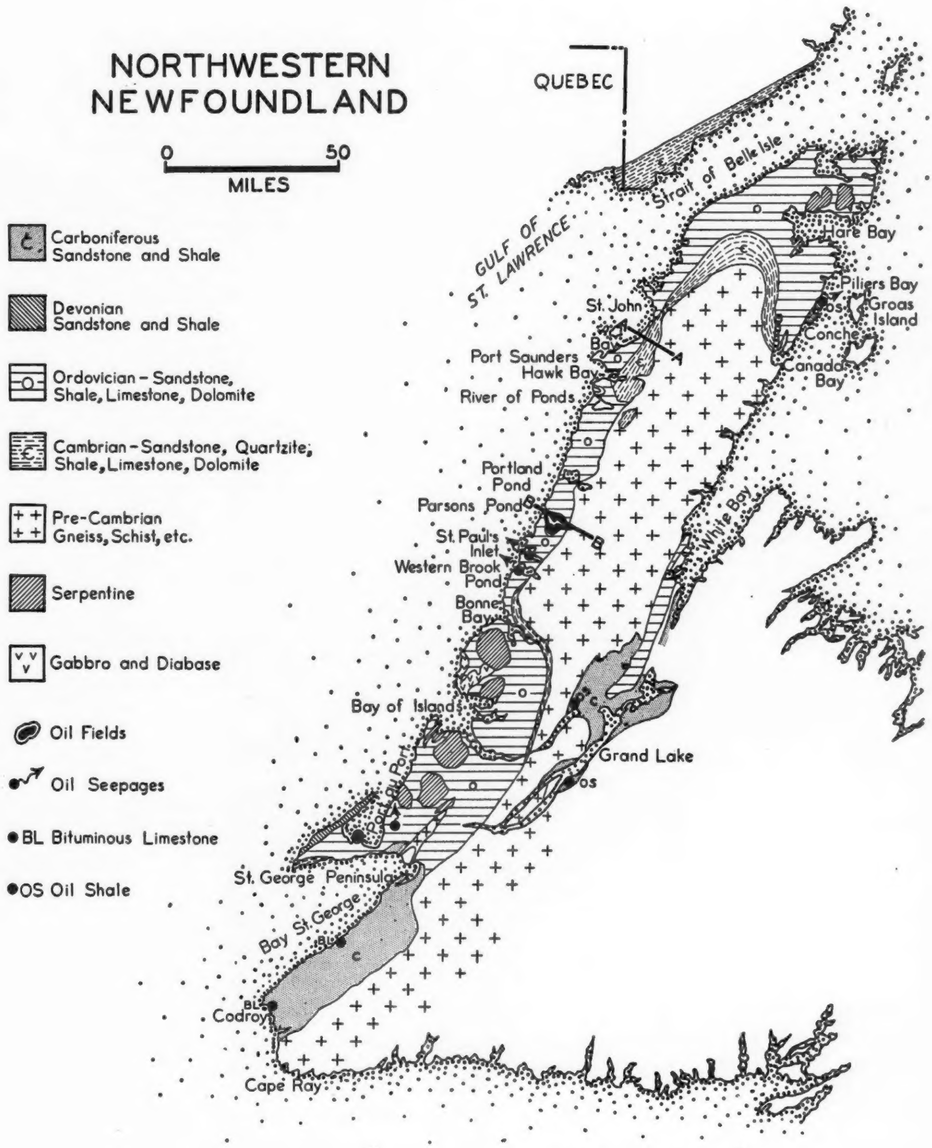

FIG. 14.—Map showing general geological features of northwestern Newfoundland.

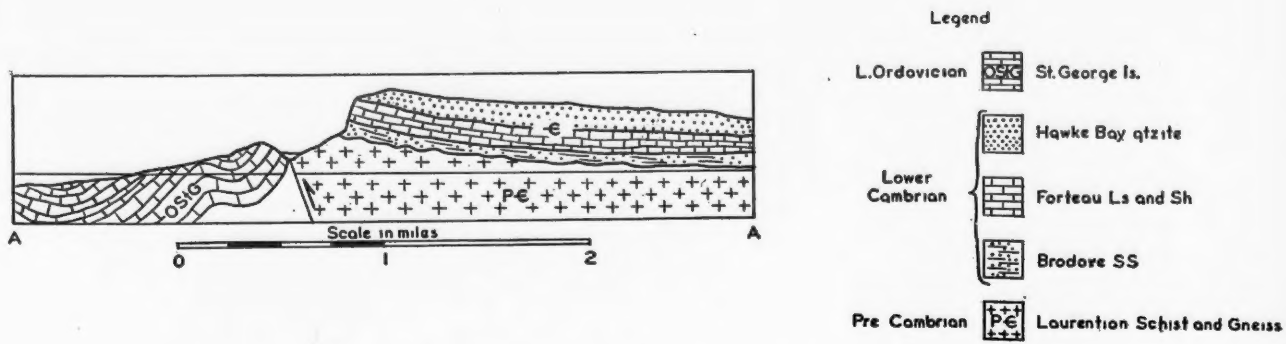

FIG. 15.—Structure section *AA* in northwestern Newfoundland. Location of section is shown in Figure 14.

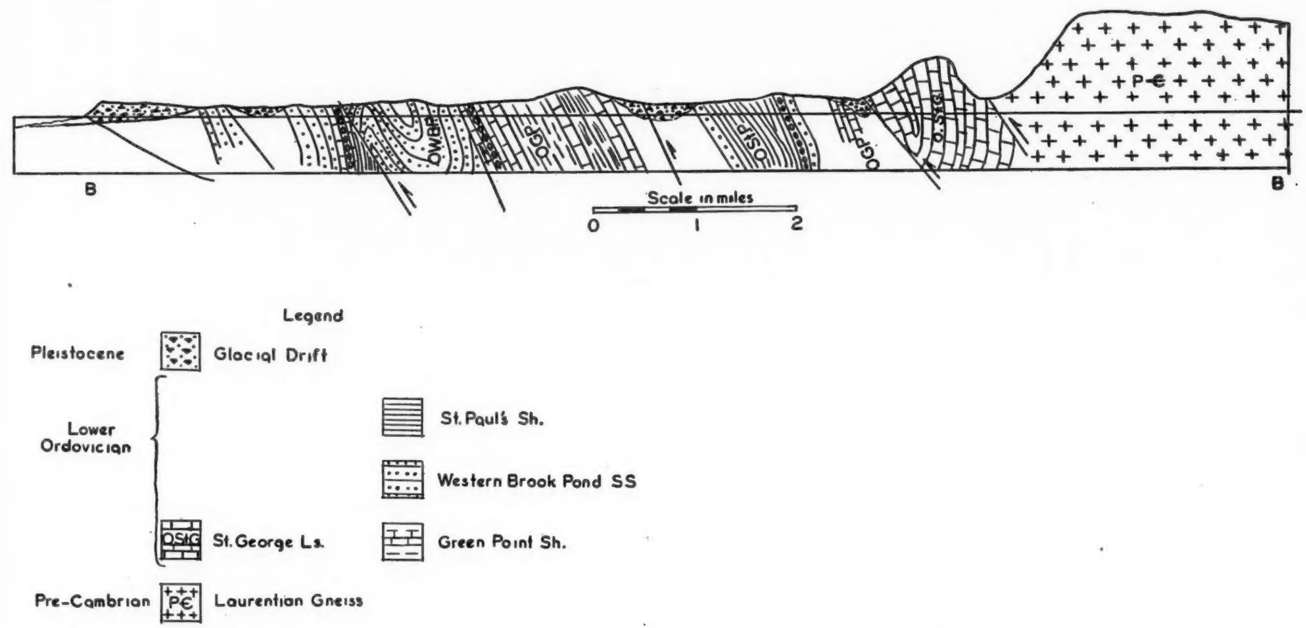

FIG. 16.—Structure section *BB* in northwestern Newfoundland. Location of section is shown in Figure 14.

nated in these beds or in some undiscovered formation below the present position of the shales can not be determined.

The oil at Parsons Pond and St. Pauls is a paraffine-intermediate to paraffinic type, having a specific gravity of 0.8008 to 0.8609 at 60°F. for the crude. Little or no gas pressure has been noted in the wells.

Surface indications of oil have been noted in Piliers Bay on the northeast coast of Newfoundland. The exposed sediments here consist of 4,000 to 5,000 feet of conglomerates, sandstones, and siltstones of Mississippian age, which form a narrow fringe along the coast for a distance of 10 miles. Only a small part of a faulted trough remains above sea-level. The visible structure includes part of a plunging anticline and syncline, broken in three places by thrust faults. The siltstones are somewhat fractured and retain residues of oil, while small seepages are noted along a fault-fracture zone. In addition to the oil seepages, a black, bituminous, or cannel shale crops out in the exposed sea cliff but is not of extensive occurrence. Analyses show it contains 36 per cent volatile matter, 35 per cent fixed carbon, and 29 per cent ash. The area does not appear to hold much promise as an economic possibility.

Bituminous shales have been described from Deer Lake and Grand Lake, in a total area of 275 square miles, in the central Carboniferous basin. These shales are associated with Carboniferous (Mississippian) shales and sandstones and vary in thickness from a few inches to 10 feet or more in a total thickness of 3,000 feet. On destructive distillation, the yields vary from 7.5 to 10.8 imperial gallons to the ton. Test drilling did not show any gas or liquid petroleum and it is doubtful if this region can be considered as a possible reserve.

The Carboniferous rocks of the Bay St. George basin are thick marine evaporites, limestones, shales, and sandstones, as well as a continental series containing coal. The total thickness of strata is not definitely known but exceeds 14,000 feet. These rocks have been folded and repeatedly thrust-faulted. One horizon in the lower part of the series consists of a vuggy fossiliferous limestone with residues of oil in the vugs. The area is covered by a thick mantle of glacial material and detailed geological work is difficult. There is a possibility that oil may be associated with the lower members of these rocks in structures as yet unmapped.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 25, NO. 8 (AUGUST, 1941), PP. 1563–1574, 4 FIGS.

POSSIBLE FUTURE-OIL PROVINCES IN EASTERN UNITED STATES

APPALACHIAN GEOLOGICAL SOCIETY[1]
Charleston, West Virginia

APPALACHIAN BASIN

The Appalachian basin as discussed in this paper is a long, narrow trough 520 miles in length, extending from eastern Kentucky northeast into southern New York. At its greatest development in the Central basin it is 320 miles in width and probably contains in excess of 30,000 feet of sediments. The entire basin is estimated to contain 210,000 cubic miles of sedimentary rocks. Shales of various colors and composition comprise more than 50 per cent of the sediments in this old basin, possibly 25 per cent being bituminous. Dolomite-anhydrite rock, dolomitic limestones, and limestones mainly of marine origin account for 30 per cent of the total sediments, 20 per cent consisting of sandstone. Only on the outer slopes of the basin in New York, Ohio, and Kentucky have wells penetrated more than 75 per cent of the sedimentary section; and in the central part of the basin in northern West Virginia and southern Pennsylvania part or all of the Silurian, Ordovician, and Cambrian lies below 10,000 feet.

There are no unconformities of great angularity in the Appalachian basin area under consideration, and those present are important more from the standpoint of their effect on regional stratigraphic relations, and should perhaps be considered rather as disconformities. The most important of such disconformities are at the base of the Pennsylvanian and the base of the Devonian. The latter is particularly noteworthy in the southwestern end of the basin where there is a truncation of the Silurian limestone series toward the Cincinnati arch. There are other disconformities throughout the stratigraphic section which are of importance locally in different parts of the basin; such, for example, as the Mississippian disconformity between the Greenbrier limestone and the Maccrady formation in West Virginia.

Near the crest of the Cincinnati arch in Ohio, and on the east flank, several wells have penetrated to the Basement complex (Fig. 1). Wells No. 1 and No. 2 encountered varying amounts of arkosic sand resting on the granitic gneiss basement. Well No. 2 is reported to have encountered brines in the sands of the Cambrian section. Other wells

[1] Committee consists of R. C. Lafferty, chairman, Owens, Libbey-Owens, Gas Department; Charles Brewer, Jr., Godfrey L. Cabot, Inc.; J. R. Lockett, Ohio Fuel Gas Company; J. E. Billingsley, Commonwealth Gas Corporation; and W. O. Ziebold, Spartan Gas Company.

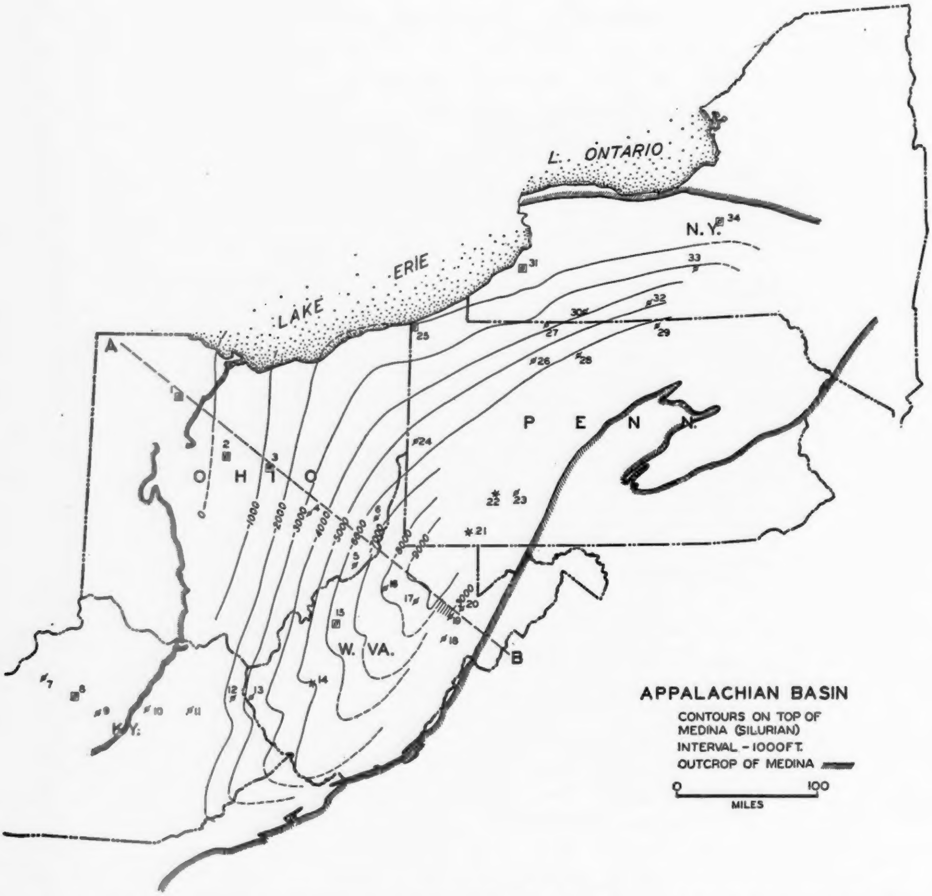


FIG. 1.—Map showing general structural features of Appalachian basin. For names and well data refer to Table I.

TABLE I

Partial Listing of Significant Deep Tests in Appalachian Basin

Map No.	Well	Operator	State	County	Feet Total Depth	Lowest Horizon Penetrated Formation	Lowest Horizon Penetrated Age	Remarks
1	Norris	—	Ohio	Hancock	2,980	Basement	Pre-Cambrian	Dry, brines
2	Vance	Wise et al.	Ohio	Delaware	4,291	Basement	Pre-Cambrian	Dry, brines
3	Wehrle†	Wehrle	Ohio	Licking	4,605	Magnesian	Ordovician	Small oil production
4	Dearth	Foraker	Ohio	Morgan	5,097	Medina	Silurian	Dry
5	Knowlton	Penn Ohio	Ohio	Washington	7,889	Medina	Silurian	Dry in Clinton. Showing gas and water in Oriskany
6	Mobley	Nat. Gas of W. Va.	Ohio	Belmont	7,887	Medina	Silurian	Dry in Clinton. Showing gas in Newburg
7	Whittaker	Boone Co. Drlg. Co.	Ky.	Selby	1,505	Knox	Ordovician	Dry, brines
8	Coleman‡	Rex-Pyramid	Ky.	Jessamine	3,200	—	Cambrian?	Dry, brines
9	Wiseman	—	Ky.	Estill	2,050	—	Ordovician	Dry, brines
10	Rose	—	Ky.	Wolf	3,807	—	Ordovician	Dry, brines
11	Elam	Swiss Oil Co.	Ky.	Morgan	1,906	Clinton	Silurian	Dry
12	Fraley	Owens, Libbey-Owens	Ky.	Lawrence	4,975	Trenton	Ordovician	Dry
13	Glenhayes	Owens, Libbey-Owens	W.Va.	Wayne	4,100	Medina	Silurian	Dry
14	Bull Crk. C. & L. Co.‖	Owens, Libbey-Owens	W.Va.	Boone	6,004	Medina	Silurian	Small gas production in Clinton, Newburg Big Six,
15	Hinzeman	United Fuel	W.Va.	Roane	9,104	Trenton	Ordovician	Dry
16	Maxwell	Columbian Carbon	W.Va.	Doddridge	7,837	Salina	Silurian	Showing oil in Oriskany; small gas in Devonian shale
17	Gribble	Hope Nat. Gas Co.	W.Va.	Harrison	10,018	Medina	Silurian	Showing gas in Oriskany
18	Simmons	Cumberland Allegany	W.Va.	Randolph	1,660	Helderburg	Devonian	Salt water in Oriskany
19	Hartman	Potter Development Co.	W.Va.	Randolph	4,480	Medina	Silurian	Salt water in Oriskany and "Clinton" sand
20	Parsons P. & L. Co.	—	W.Va.	Tucker	4,250	Oriskany	Devonian	Salt water in Oriskany
21	Piedmont Coal Co.*	Peoples Gas Co.	Penn.	Fayette	6,825	Oriskany	Devonian	Gas in Oriskany and Onondaga
22	Booth & Flynn**	Peoples Gas Co.	Penn.	Westmoreland	7,756	Salina	Silurian	Small amount gas in Oriskany and Salina
23	Bank of Indiana	Potter Development	Penn.	Westmoreland	7,725	Oriskany	Devonian	Gas in Onondaga. Water in Oriskany
24	Tennis¶	Galey & Duff	Penn.	Beaver	4,613	Medina	Silurian	Salt water in Oriskany. Showing gas in Big Six horizon (Silurian)
25	Childs	Ohio Oil Co.	Penn.	Erie	5,191	St. Peter Horizon	Ordovician	Showing oil and gas in Trenton and St. Peter horizons
26	James	United Natural	Penn.	Elk	7,925	Medina	Silurian	Dry
27	Derrick City	Bradford Deep Well Co.	Penn.	McKean	5,820	Medina	Silurian	Dry in Medina. Showing oil in Oriskany
28	Crawford	Potter Development	Penn.	Potter	8,482	Medina	Silurian	Dry
29	Shoemaker	Lycoming	Penn.	Tioga	7,148	Salina	Silurian	Dry
30	Cady	—	N.Y.	Allegany	6,500	Medina	Silurian	Salt water in Oriskany. Dry in Medina
31	Butler	—	N.Y.	Erie	4,602	Basement	Pre-Cambrian	Showing gas in Trenton
32	Collins	G.L.C. Inc.	N.Y.	Steuben	6,825	Medina	Silurian	Showing gas, salt water in Medina
33	Farkus	Reserve Oil Co.	N.Y.	Tompkins	6,210	Trenton	Ordovician	Dry
34	Yenny	Lupher & Cline	N.Y.	Onondaga	4,679	Potsdam	Cambrian	Dry

† Five producing oil wells.
‡ Composite record.
‖ Two small Clinton gas wells in this immediate area.
* Discovery well of this gas pool was the Summitt Hotel No. 1, of Potter Development Co. *et al.*, which was originally completed in the Onondaga chert beds above the Oriskany.
** Two more wells were drilled to the Oriskany in this immediate area.
¶ This well is on the edge of a small Oriskany sand gas pool.

drilled on the east flank of this arch have encountered black shales in this section which are not present in wells near the crest of the arch. In Kentucky well No. 8 encountered brines, some gas, and possibly some dark oil from these rocks.

In northeastern Ohio scattered wells have been drilled to the St. Peter horizon (Ordovician), in some of which St. Peter type sand has been reported. No commercial wells have been developed in these areas but copious "blue-lick" sulphur water has been encountered. Recently well No. 25, on the Ohio-Pennsylvania line, was drilled to the St. Peter sand (Ordovician) in which a showing of oil and gas was encountered. In Kentucky wells No. 7, No. 8, No. 9, and No. 10 encountered copious brines and some gas at this horizon. One well, No. 9, encountered more than 50 feet of St. Peter type sand. The farthest east and stratigraphically deepest wells in the basin to encounter oil and some gas are the several wells represented by well No. 3. Commercial oil and water is produced from either the St. Peter horizon or from the upper part of the lower Magnesian group of dolomites.

In central New York several wells have been drilled to or through the Potsdam sand of the Cambrian, which in a few places showed gas. More commonly, however, it is a water horizon. Well No. 31, in western New York, was bottomed in granite; and a near-by well was drilled 27 feet into the Potsdam. Well No. 34, in central New York, near Syracuse, drilled about 50 feet in this formation. None of these wells reported any oil, gas, or salt water in the Potsdam.

In northwest Ohio commercial oil with some gas and in places copious brines have been developed in the Trenton (Ordovician), where it is dolomitic. In central Kentucky some production has been encountered from the same formation. In central New York small amounts of gas have been found in this limestone, but due to its non-dolomitic character and low porosity it is not very promising as a commercial oil- and gas-producing formation throughout the state. Other possible producing zones of the Ordovician of the northern end of the basin are the sandy zones found in the black Hudson River and Utica shale formations. Southern New York and northern Pennsylvania are relatively untested in these formations but would require drilling depths of 9,000 to 10,000 feet. In the central part of the basin, in Roane County, West Virginia, only one well—No. 15—has penetrated the stratigraphic section to the Trenton. This well was drilled to the total depth of 9,104 feet, stopping approximately 300 feet in this formation. It encountered no porosity in the Trenton but did not penetrate the entire "Trenton lime" section.

Commercial oil and gas have been developed in Ohio from the Silurian "Clinton sand" (Medina). This production is in a belt trend-

ing slightly east of north across the central part of the state, approximately 25 to 40 miles wide. Numerous wells have penetrated to this horizon in Kentucky but have encountered very little sand and no commercial production. In western New York this sand is the lowest commercial gas-producing formation, but to date it has proved unproductive in eastern Ohio and in western Pennsylvania (where it has been adequately tested only in the northwest corner). This formation has been tested in West Virginia in the western part of the state by scattered wells without success. Recently two small gas wells, represented by No. 14, have been completed in this sand which is approximately 60 feet in thickness. Well No. 17, in Harrison County, West Virginia, has just been completed through this sand at 10,018 feet and the latter is reported as hard, quartzitic, and impervious throughout, with no oil, gas, or water showing. Well No. 19, on the steep eastern flank of the basin in Randolph County, West Virginia, was drilled through the Clinton sand, which was likewise devoid of oil or gas. In the deeper parts of the basin throughout Pennsylvania, exploration for this (and deeper sands) is hampered by the tremendous thickness of the Upper Silurian red shales, sandstones, and evaporites, which, from past exploration in northern Pennsylvania and southern New York, appear unfavorable for the accumulation of oil and gas. At the outcrop in central Pennsylvania there are more than 7,000 feet of Silurian strata exposed.

In the Devonian-Silurian limestone section ("Corniferous" of Kentucky and southern West Virginia, "Big lime" of Ohio) several dolomitic or sandy zones of porosity occur. Most important of these is the Oriskany sandstone (Lower Devonian) which has produced commercial gas in New York, Pennsylvania, and West Virginia; and oil and gas in Ohio. This horizon has been fairly thoroughly explored on the northern and western slopes of the basin (southern New York, northern Pennsylvania, and northeastern Ohio). In the central part and on the eastern flanks, particularly in West Virginia and Pennsylvania, there has been relatively little exploration. At Uniontown, Pennsylvania (well No. 21), commercial amounts of gas have been developed on the Chestnut Ridge anticline from the Oriskany and overlying Onondaga chert beds. In well No. 23, on the Laurel Ridge anticline in Westmoreland County, Pennsylvania, gas was encountered in the chert beds; and salt water in the Oriskany. In the same county at Ligonier, three wells were drilled to the Oriskany formation which produced small amounts of gas. One of these (well No. 22) was drilled about 950 feet below the Oriskany into the Silurian section. Tight Oriskany sand, with a showing of oil, was encountered at well No. 16 in Dodderidge County, West Virginia. In well No. 17, now

A

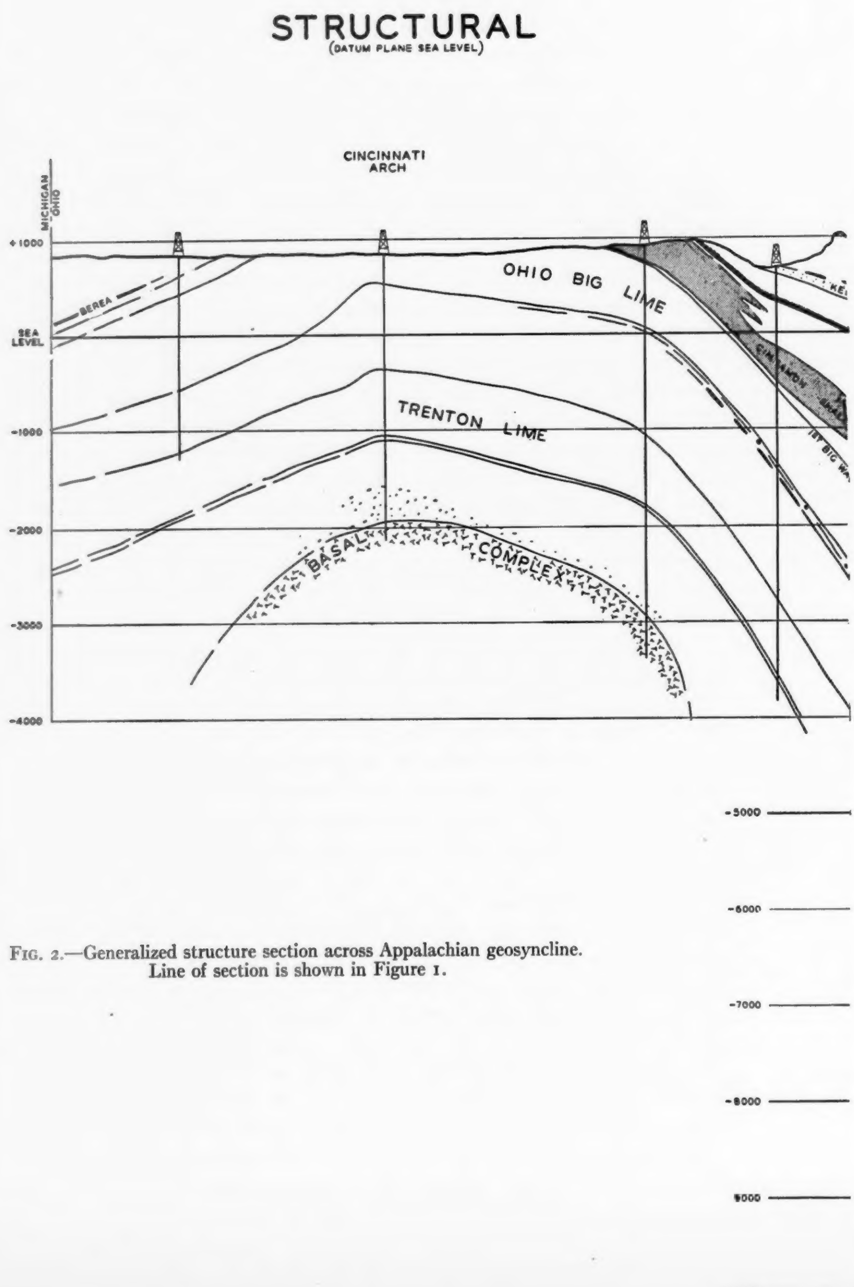
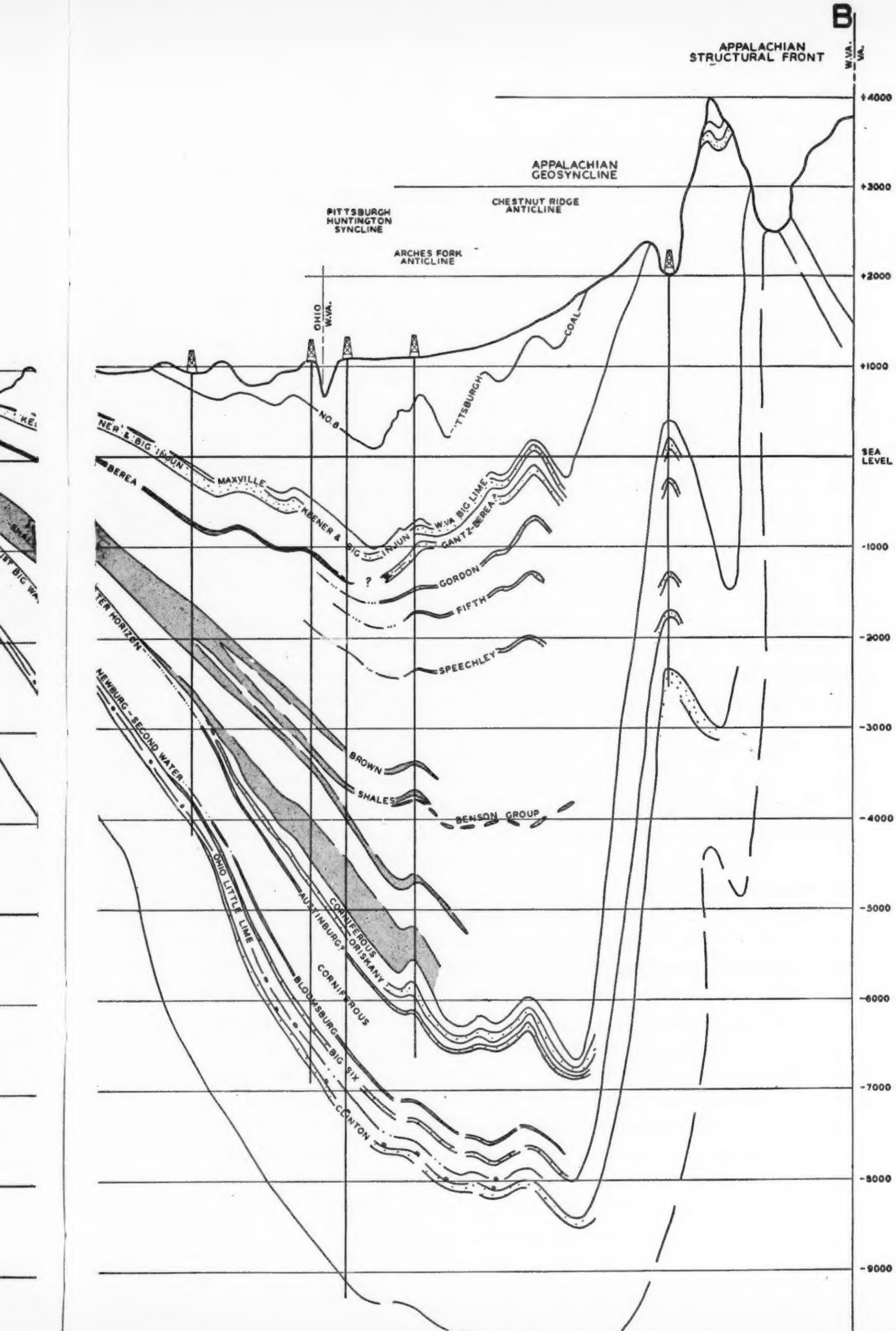


FIG. 2.—Generalized structure section across Appalachian geosyncline. Line of section is shown in Figure 1.



B
APPALACHIAN STRUCTURAL FRONT
W.VA.
VA.
APPALACHIAN GEOSYNCLINE
CHESTNUT RIDGE ANTICLINE
PITTSBURGH HUNTINGTON SYNCLINE
ARCHES FORK ANTICLINE
OHIO
W.VA.
+4000
+3000
+2000
+1000
SEA LEVEL
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10,000
COAL
NO. 8
MAXVILLE
KEENER & BIG INJUN
BEREA
W.VA BIG LIME
GANTZ-BEREA?
GORDON
FIFTH
SPEECHLEY
BROWN
SHALES
BENSON GROUP
CORNIFEROUS
ORISKANY
AUSTINBURG?
OHIO LITTLE LIME
NEWBURG - SECOND WATER
BLOOMSBURG
BIG SIX
CLINTON

being tested, a small amount of gas in the Oriskany was reported on a drill stem test. Wells No. 18, No. 19, and No. 20, on the eastern slope of the basin in West Virginia, have all tested the Oriskany without success, but all had showings of salt water in the formation, indicative of porosity. They were drilled on large closed surface structures. It should be noted that the Oriskany sandstone crops out in the mountains on the eastern side of the basin from New York to Virginia and is probably present under most of the central parts of the basin.

Another important porous zone in the Silurian on the western side of the basin is the Newburg sand. In Kentucky the Newburg has produced commercial oil near well No. 10. In Ohio commercial gas and some oil have been developed from the same general stratigraphic section, near Lake Erie in northeastern Ohio. Throughout Ohio this horizon consistently contains water. In West Virginia one well (No. 14) has produced gas; but several miles north, water has been encountered in several wells at structurally lower levels.

The lowest of the zones of porosity, associated with the Devonian-Silurian limestone series, is the Big Six sand at the base. In Kentucky, south and west of well No. 12, there has been commercial gas production from this horizon. In West Virginia, immediately north of well No. 13, commercial production of gas has been developed, and one of the wells at No. 14 encountered commercial amounts of gas from this horizon. No other production is known to have been developed at this horizon, which has been penetrated in only a few wells in the basin proper.

Other zones of porosity are known to occur in the "Corniferous-Big lime" section of Kentucky and Ohio that are consistent carriers of water. Under favorable structural conditions these should be potential sources of oil and gas.

The Upper Devonian, the Mississippian, and the Pennsylvanian contain the pay sands of the old Appalachian oil fields which to-day are largely depleted. This part of the stratigraphic section is not completely explored in the deeper parts of the basin, but directed exploration is difficult due to the predominantly lenticular nature of the pay zones. Furthermore, the unexplored parts of the basin are more likely to yield gas than oil. Showings of gas and small gas wells occur throughout the entire length of the basin east of the old Appalachian fields, some of them within sight of the faulted mountain front.

In conclusion, exploration for new oil reserves in the Appalachian area has been retarded during the past two decades by larger reserves of flush oil in other parts of the country and the difficulties of deep drilling in the exceptionally hard formations of the area.

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NORTHERN CINCINNATI ARCH AREA

An early pre-Cambrian mountain range reached from Wisconsin into Illinois and diagonally across Indiana, connecting with another chain which extended from the present Canadian shield through western Ohio. These were base-leveled and covered by an overlap of Cambrian sediments in the west and by Ordovician and older rocks on the east. The southward-plunging crystalline cores of these uplifts covered by sedimentary rocks, remained as more or less positive elements separating the basins into which the bulk of the mountains had been deposited as sediments. They form the present Kankakee arch, Wabash spur, and Cincinnati arch. By the time the highlands had disappeared, the weight of the basins was sufficient to cause downwarping along the trends of the old mountain chains in the areas where the basins were nearest together. This subsidence continued as the sediments in the basins became heavier.

In western Ontario, between the Michigan basin and the great Appalachian basin, the basal complex which had been covered at the south by Lower Ordovician, Cambrian, and pre-Cambrian beds went under the sea at the beginning of Trenton time and has since dropped at least 2,500 feet, leaving a buried dome of gneissoid granite within less than 3,000 feet of the present surface in northwestern Ohio. This has been reached in wells No. 1, No. 2, and No. 3 (Fig. 3).

In the Logansport sag in north-central Indiana between the Michigan and Illinois basins, 2,431 feet of sub-Trenton sediments have been

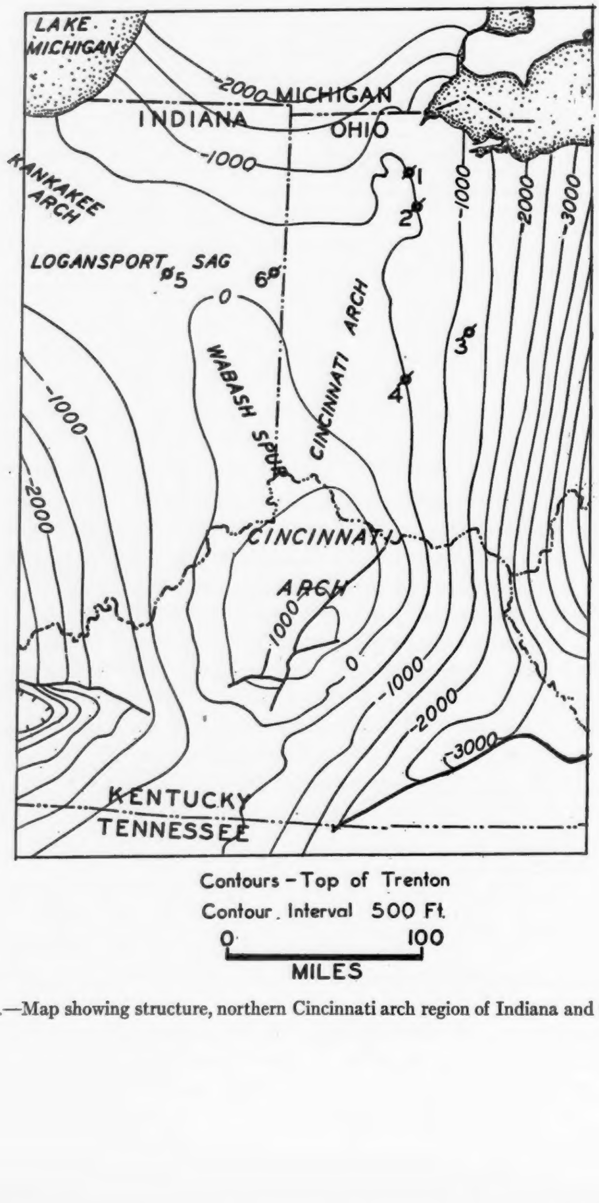

FIG. 3.—Map showing structure, northern Cincinnati arch region of Indiana and Ohio.

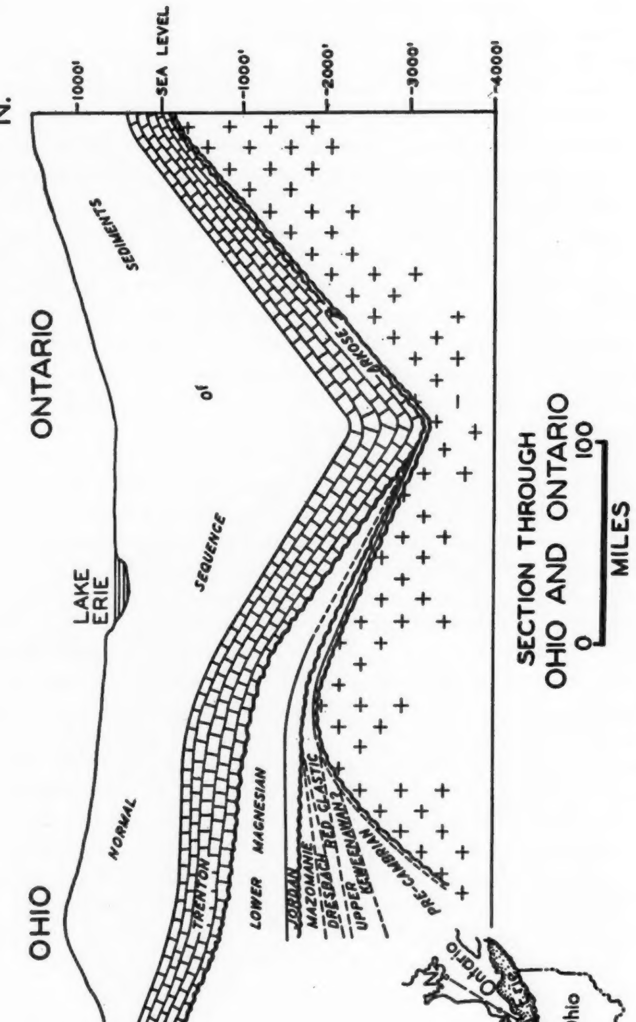

FIG. 4.—Structure section across Ohio and Ontario.

penetrated in a well near Kokomo (No. 5) which was reported to have reached the Bayfield sandstone of Algonkian age.

Near Bryant, in Jay County, Indiana, midway between the Cincinnati arch and the Wabash spur, 1,720 feet of sub-Trenton strata was encountered in a well (No. 6) which was reported to have reached the Cambrian, Eau Clair, sandstone. The sediments which thicken toward the Michigan basin in northeastern Indiana and northwestern Ohio have not been drilled below the Trenton. At least 7,000 cubic miles of untested sedimentary rocks are present, therefore, in that area.

In the Friend well, No. 4, in Greene County, Ohio, near the axis of the Cincinnati arch, 800 feet of Ordovician, 1,185 feet of Cambrian, and 807 feet of pre-Cambrian, a total of 2,792 feet of sub-Trenton beds, were encountered and the basal complex was not reached. This well indicates that the thickness of unexplored sub-Trenton sediments is at least 5,000 feet where the crest of the arch crosses the Ohio River. These contain many sandstones, dark limestones, and dolomites. The total of unexplored sediments present in southwestern Ohio and southeastern Indiana may be conservatively estimated at 9,000 cubic miles.

Between the Findlay field (No. 2) and Delaware County, Ohio (No. 3), the crystalline surface dips southeast about 1,000 feet. The Vance well, in Delaware County, which penetrated 1,100 feet of sub-Trenton sediments before encountering gneissoid granite is comparatively high on the granite ridge underlying the arch. East of this well no information is available on the contour of the crystalline floor. However, the relatively great thickness of Cambrian and pre-Cambrian sediments present where the basal complex plunges south in Greene County (No. 4), the weight of several miles of sediments deposited in the great Paleozoic basin at the east, and the depth of the Trenton, approximately 12,000 feet below sea-level in the Pittsburgh-Huntington basin, indicate that at least 10,000 to 12,000 feet of sediments are present under the eastern and southeastern borders of Ohio. That area can be considered as having been prospected to a depth of 5,000 feet. The undeveloped sediments underlying the eastern half of the state total at least 28,000 cubic miles, making a total of 41,000 cubic miles for the northern Cincinnati arch region.

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VOL. 25, NO. 8 (AUGUST, 1941), PP. 1575-1586, 3 FIGS.

POSSIBLE FUTURE OIL PROVINCES OF SOUTHEASTERN UNITED STATES

MISSISSIPPI GEOLOGICAL SOCIETY[1]
Jackson, Mississippi

GEORGIA

The state of Georgia occupies 59,265 square miles of which 35,000 square miles, or 59 per cent, are covered by Coastal Plain deposits. The remainder of the state is covered by basement rocks, though a small area in the northwest corner is occupied by Paleozoic formations. The sediments vary in thickness from zero at the contact of the sedimentary-basement complex to approximately 2,500 feet on the coast at the northeast corner of the state; at the southeast corner on the coast approximately 5,000 feet; and at the southwest corner at the Georgia-Alabama line the sediments are probably in excess of 7,000 feet. Using an average thickness of one-half mile for the sediments gives a total volume of 17,600 cubic miles.

All of north Georgia is covered by basement igneous rock with the exception of a small area in the northwest corner of the state which is covered by highly folded Paleozoic formations. In south Georgia, the sediments range in age from Cretaceous to Recent, of which probably 90 per cent are marine, and are composed of limestone, chalk, marine sands, and shale. The 10 per cent of non-marine section is composed of sand and shale.

Some of the formations are characterized by stratigraphic overlaps due to progression and regression of the sea; consequently, strand-line conditions should exist in the section. The regional structure of the Coastal Plain of Georgia is that of a south-southeast-dipping homocline, and it is thought that the normal dip of these beds may be interrupted at a few points by local structures.

No commercial production of oil or gas has been obtained in Georgia, but there have been a few showings in wells drilled. These showings have occurred in sediments of Miocene, Wilcox, and Eutaw ages. Several oil seeps are known to exist and others have been reported.

Oil and gas development in Georgia has probably been retarded due to the relatively thin section of sedimentary beds. There have not

[1] Committee consists of Henry N. Toler, chairman, Southern Natural Gas Company; David C. Harrell, Carter Oil Company; Urban B. Hughes, consulting geologist; Harry E. Lillibridge, Eason Oil Company; V. C. Maley, Humble Oil and Refining Company; D. J. Munroe, Sun Oil Company; with the assistance of Arthur C. Munyan, State Division of Mines, Georgia; Kendall E. Born, State Division of Geology, Tennessee; and Robert B. Campbell, Tampa, Florida, consulting geologist.

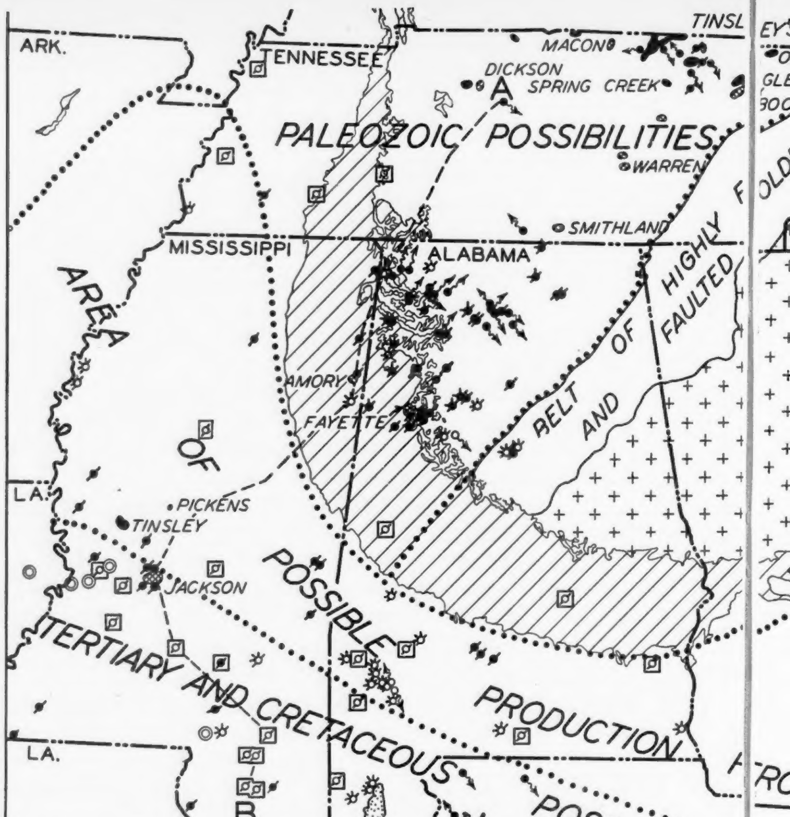
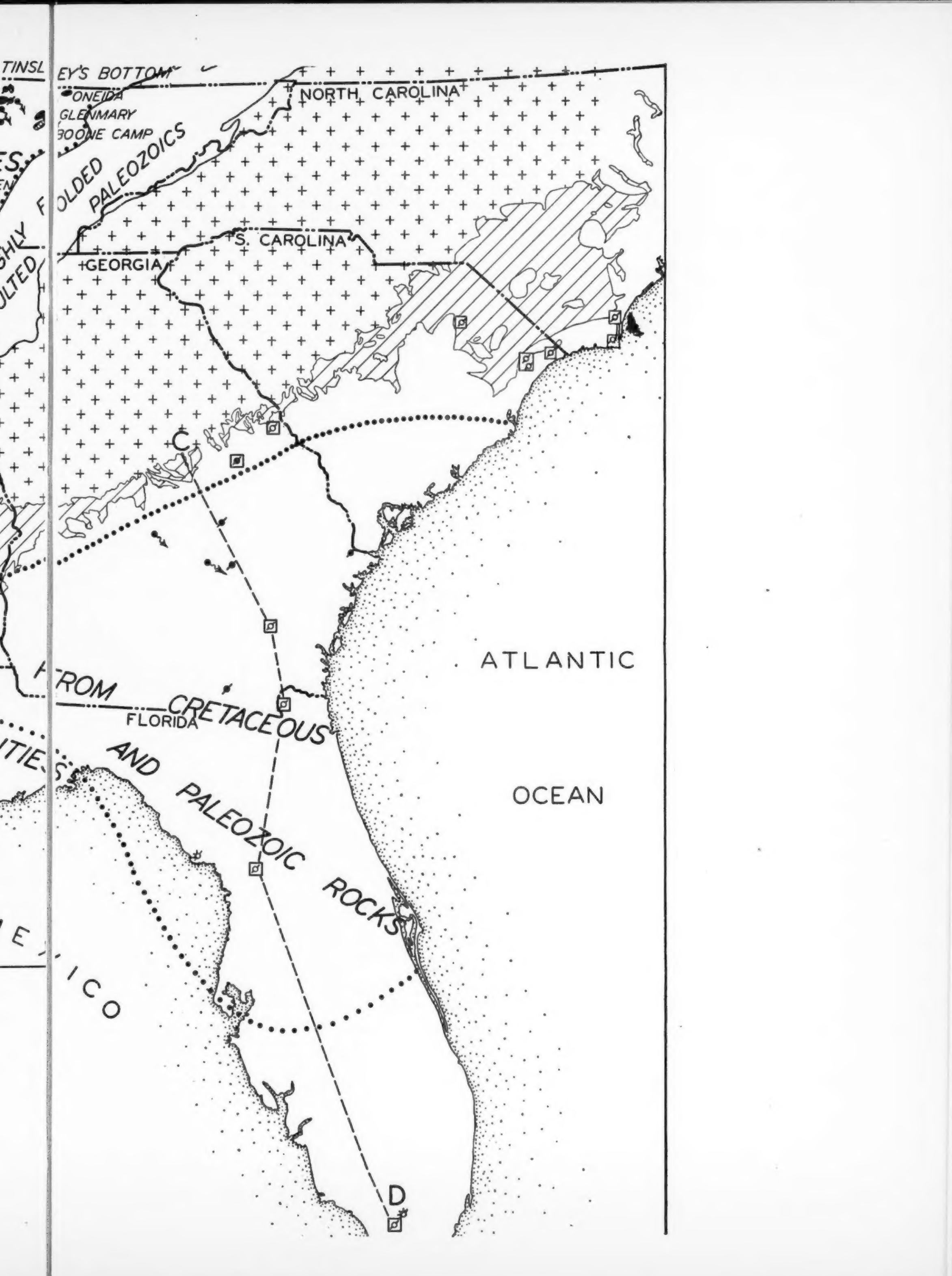


FIG. 1.—Map showing general features of southeastern states. Double circles indicate salt domes.



TINSLEY'S BOTTOM
ONEIDA
GLENMARY
BOONE CAMP
NORTH CAROLINA
FOLDED PALEOZOICS
S. CAROLINA
GEORGIA
C
ATLANTIC
OCEAN
FROM CRETACEOUS
FLORIDA
AND PALEOZOIC ROCKS
MEXICO
D

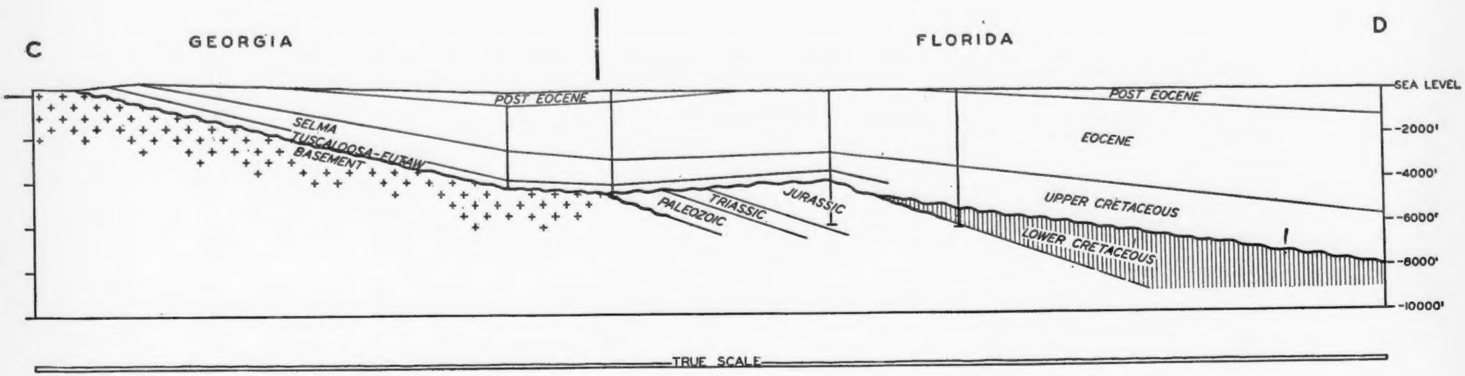


FIG. 2.—Generalized structure section *CD* from Georgia through Florida. Line of section shown in Figure 1.

been prolific showings of oil and gas in wells drilled and very few pronounced and well defined structures are known. Also, no commercial oil or gas fields have been found in any of the areas adjacent to the state.

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FLORIDA

The state of Florida comprises approximately 54,860 square miles and is underlain by marine sediments to depths varying from 5,000 feet to more than 15,000 feet and having a volume in excess of 128,000 cubic miles. These sediments consist of approximately 75 per cent limestone or similar calcareous rocks and 25 per cent sands and shales, with a negligible amount of evaporites. The percentage of limestone varies from an approximate 50 per cent in the north to almost 100 per cent in the south part of the peninsula. In age, the formations range from pre-Paleozoic metamorphic rocks to Recent sediments; the larger part being Cretaceous and Tertiary.

Significant regional unconformities are known to be present at the top of the Paleozoic and at the base of the Upper Cretaceous in the north part of the state. The regional structure is that of a south-dipping homocline, modified by the presence of the very large Ocala structural uplift in the northwest part of the peninsula. The Upper Cretaceous overlaps all the older formations from south to north and probably rests on metamorphic rocks locally in the north part of the province.

Significant showings of oil are not known but gas has been encountered in at least two deep wells and is reported in numerous water wells and springs. Generally, these showings are in Tertiary rocks although a well at Cedar Keys reported gas in the Cretaceous.

The possible presence of closed structural and stratigraphic traps; the known existence of a thick Tertiary and Upper Cretaceous section over the entire area; the presence of a wedge of Lower Cretaceous and possible older material in the south part of the peninsula, and also the known occurrence of Paleozoic rocks within reach of the drill, certainly justify the classification of this area as a potential oil province.

The progress of exploration in Florida has been retarded by the existence of conditions which make present exploration methods difficult or ineffectual. A covering of Recent materials hampers detailed surface mapping, and the difficulty experienced in obtaining dependable seismic reflections has discouraged this type of work. The value of gravity and magnetic surveys is as yet unknown.

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SOUTH ALABAMA

The south half of Alabama comprises 22,000 square miles and is underlain by a sedimentary section varying in thickness from zero at the contact of the sedimentary basement complex to possibly more than 15,000 feet on the coast in the vicinity of Mobile. The total volume of these sediments is probably in excess of 45,000 cubic miles.

The areas are covered by sediments of Cretaceous, Tertiary, and Recent ages and are composed of about 40 per cent shales, 40 per cent sand, and 20 per cent limestone, of which 75 per cent is marine and 25 per cent non-marine.

A large regional unconformity is known to be present at the base of the Upper Cretaceous as this formation rests directly on igneous rocks in northeast-central Alabama and on Paleozoic formations in the central part of the state. Downdip, beds of Lower Cretaceous age are known to wedge in and probably rest on igneous rocks and rocks of Paleozoic age. Very few wells have penetrated these beds of Lower Cretaceous age; consequently, very little information is available concerning the possible large regional unconformity between the Upper and Lower Cretaceous. Unconformities probably of less magnitude are known to exist at the top of the Cretaceous, at the top of the Wilcox, possibly at the top of the Claiborne, and possibly at the top of the Oligocene.

The regional structure of south Alabama is that of a south-southwest-dipping homocline with the surface formations dipping about 10 to 15 feet per mile toward the south in southeast Alabama and approximately 20 to 25 feet per mile south by southwest in the southwest part of the state. The subsurface dip is somewhat greater due to the

thickening of the formations southward. Several formations are present downdip which do not exist at the outcrop. This normal south-southwest-dipping homocline is interrupted in southwest Alabama by two large well known structural features, namely, the Hatchetigbee anticline and the Jackson fault, which are located in Choctaw, Clarke, and Washington counties.

About 100 wells have been drilled for oil and gas, of which only a few were deeper than 3,000 feet. Many of the wells have had showings of oil and gas and some drilled 30 or 40 years ago are making enough gas at present to verify the gas showings. In some wells drilled near Mobile, there were several showings of oil and gas with the gas being found at depths ranging from 1,500 to 2,000 feet, apparently in sands of Miocene age, but by some considered Vicksburg or Jackson in age. Gas seeps are found along the Jackson fault and Hatchetigbee anticline.

Several dry holes on the Hatchetigbee anticline and the Jackson fault, which went to a depth sufficient to test the Eutaw and in some places the Tuscaloosa, have contributed more to retarding development in south Alabama than any other one factor.

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NORTHWEST ALABAMA

The Warrior Basin occupies an area of 7,500 square miles in northwestern Alabama. It lies between the Nashville dome of Tennessee and the sharp northeast-southwest-trending Appalachian folds in the vicinity of Birmingham. The sediments in the basin range in age from Cambro-Ordovician to Pennsylvanian. As they have a combined thickness of 7,000 feet and an average thickness of approximately one mile, their volume is estimated to be 7,500 cubic miles. These sediments are marine and lagoonal deposits which are estimated to be 60 per cent limestone and dolomite, 25 per cent sand, and 15 per cent shale. Numerous coal beds are present in the Pennsylvanian.

The evidences for the occurrence of oil and gas are the old Fayette Gas field in Fayette County and outcrops of asphaltic sands and limestones of Chester age across the north rim of the basin and numerous showings of oil and gas in wells in the entire area. These showings of

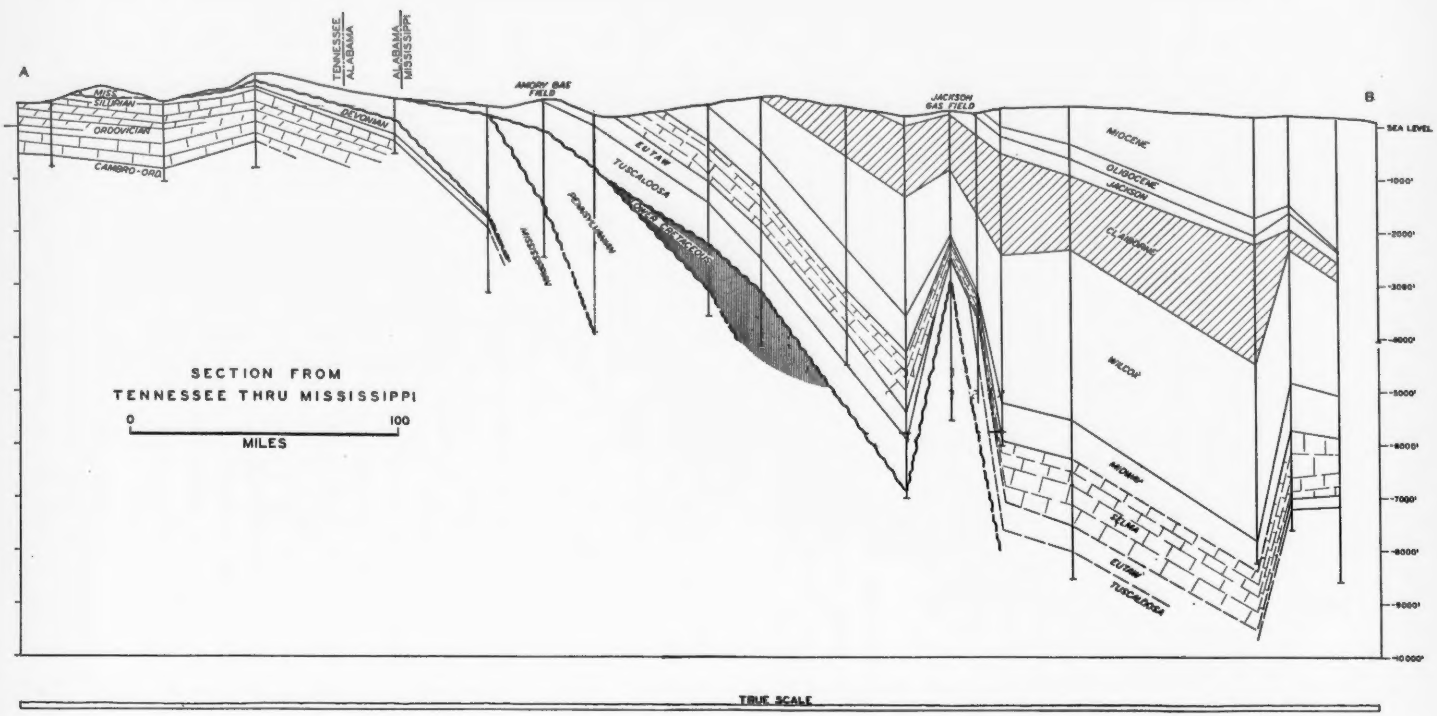

FIG. 3.—Generalized structure section *AB* from Tennessee through Mississippi. Line of section shown in Figure 1.

oil and gas occur throughout the section from the Ordovician to the lower Pottsville.

Good showings of oil and gas have been recorded from the Knox (Cambro-Ordovician) in Winston, Franklin, and Madison counties, and good showings from the Trenton (Ordovician) in Lawrence and Franklin counties. Mississippian limestones are producing a small amount of oil in Madison County and numerous oil showings have been noted in the Bethel sand, Gasper limestone, and Hartselle sandstone throughout the area. Especially good showings of oil were obtained in the Hartselle sandstone (Chester) in the Shannon wells near Jasper, in Walker County. Gas in commercial quantities was produced for a number of years in the Fayette gas field from the lower Pottsville sandstone.

The structure of the Warrior Basin shows a low regional dip toward the south-southwest in the older beds and toward the southwest in the Pennsylvanian beds. This low dip appears to continue across the basin almost to the Appalachian region where the beds are highly folded and faulted. The individual structures in the basin appear to be small and northwest-southeast normal faulting is common. Marked unconformities exist at the base of the Silurian, Devonian, Mississippian, and Pennsylvanian systems.

Exploration in this area has been retarded because of the lack of outstanding structures and because of the indurated section which has to be penetrated.

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MISSISSIPPI

The state of Mississippi covers 46,865 square miles and is underlain by a sedimentary section varying from a thickness of 5,000 feet in a small area in northwest Mississippi to a thickness in excess of 15,000 feet in the greater part of the state. The total volume of sedimentary section probably exceeds 140,000 cubic miles.

Practically the entire geologic column from Ordovician to Recent is represented. In northeast Mississippi, wells have penetrated several hundred feet into the Knox dolomite (Cambro-Ordovician). The formations become progressively younger toward the south and southwest and in the most southern part of the state as much as 4,000 feet of Miocene beds have been penetrated.

The sediments are composed of approximately 60 per cent marine and 40 per cent non-marine material, of which approximately 40 per cent is shale, 40 per cent sand, and 20 per cent limestone. Some of the formations become more marine and calcareous from the outcrop downdip toward the south and southwest; toward the east and southeast, the same condition is true.

A large regional unconformity is known to be present at the top of the Paleozoic. At and near the outcrop Upper Cretaceous rests directly on rocks of Pennsylvanian and Mississippian age. Downdip, rocks of Lower Cretaceous age are known to wedge in and rest on Pennsylvanian. Very little is known concerning the possible large regional unconformity between Upper Cretaceous and Lower Cretaceous. There are smaller unconformities probably of less importance at the top of the Cretaceous, the top of the Wilcox, and the top of the Claiborne.

There are known to be pinch-outs of some formations around structural features, such as the Jackson dome, the Sharkey platform, some piercement salt domes, and possibly on other structures. All formations that may be present between Upper Cretaceous and Paleozoic have to wedge out updip as none of them is represented at the surface.

The regional structure of Mississippi is that of a west- and southwest-dipping homocline at approximately 30 feet to the mile into the Mississippi embayment. This normal picture is interrupted by such large structural features as the Jackson dome, Tinsley dome, Kilmichael dome, Sharkey platform, the south-central Mississippi salt basin, and the large feature in southern Mississippi known as the Wiggins structure, which forms the southern boundary of the salt basin. This major uplift probably extends a considerable distance toward the west or northwest. In this south-central Mississippi salt basin, five salt domes have been proved by the drill and many others probably exist. In north Mississippi, the Paleozoic beds probably have been affected by the Cincinnati arch, regardless of whether it continues in a southeasterly direction and plunges under Cretaceous beds in Mississippi, or whether it turns west.

In addition to the Tinsley oil field, the smaller Pickens oil field, the Jackson gas field, and the Amory gas field, evidences of oil and gas have been found in several wildcat wells in different parts of the state. Approximately twenty wells have had showings of oil or gas, and these showings have occurred in formations ranging in age from Ordovician to Miocene. The more significant have been in beds of Cretaceous age. Around the flanks of the Jackson dome, several wells have had oil showings and 25,000 barrels of heavy oil have been produced on the

southeastern edge of the field. One oil seep is known in Wilkinson County, and there are a few questionable gas seeps.

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TENNESSEE

The area in Tennessee favorable for oil and gas production approximates 30,000 square miles. The only areas definitely condemned are the Appalachian Valley and Ridge and the Great Smoky Mountains. The sediments include beds from Recent to Cambro-Ordovician in age, furnishing an estimated gross volume of 35,000 cubic miles.

West Tennessee is underlain by beds of Upper Cretaceous and Tertiary ages with a thickness varying from zero to 3,300 feet and consisting of 60 per cent sand, 15 per cent marl, and 25 per cent shale. Below this is a little known Paleozoic section consisting of undetermined percentages of dark limestone, shales, and some dolomite.

In middle Tennessee there is a composite thickness of 7,000 feet composed largely of Paleozoic limestones, shale, and cherty limestones with some sandstone which is in the Pennsylvanian.

Unconformities occur in the Tertiary and Upper Cretaceous and at the base of Paleozoic systems, but probably the most pronounced unconformity occurs at the Upper Cretaceous-Paleozoic contact. In western Tennessee the regional dip is west and southwest into the Mississippi embayment at a rate of 25 to 30 feet per mile. Little is known of structural trends but the presence of relatively old Paleozoic rocks immediately below the Cretaceous suggests a possible continuation of the trend of the Nashville dome through this part of the state.

In middle Tennessee the major structural feature is the Nashville-Cincinnati axis, bordered on the east by a synclinal area, on the west by a structural "low" between the Nashville dome and the West Tennessee arch. This regional fold is interrupted by local features.

In west Tennessee, gas seeps are present along the Mississippi flood plain at and near Memphis. Oil and gas showings have been reported in the Upper Cretaceous in at least a dozen wells and Paleozoic showings have been recorded in two wells. The nearest Paleozoic pro-

duction is in the west Kentucky coal basin and the nearest Upper Cretaceous production is in the Tinsley field, in Mississippi.

In middle Tennessee, commercial production (small) has been found in (1) lower and middle Mississippian strata in Morgan, Scott, and Overton counties; (2) probably Devonian gas in Robertson County; (3) Silurian rocks in Dickson and Sumner counties; (4) in rocks of Ordovician (Trenton, Black River, and Stones River) age in Clay, Jackson, Overton, Pickett, and Fentress counties; (5) Cambro-Ordovician strata (Knox dolomite group) in Clay, Pickett, and Fentress counties. Oil seeps are known in Ordovician rocks in Davidson, Clay, Fentress, Overton, and Pickett counties and in Silurian strata in Lincoln County. Deeper possibilities (Knox) are essentially unknown. Porous zones have been encountered in Canadian rocks in more than 35 wells. The northern part of the Cumberland plateau, in which productive formations of Clay and adjoining counties have not been tested, and the northwestern flank of the Nashville dome, where Devonian strata are known to be present and Ordovician section may include porous zones, must be considered as the most favorable areas for prospecting.

Exploration has been retarded because of (1) the covering of loess in west Tennessee; (2) the difficulty of mapping geology in the west area; (3) the presence of fresh water in Upper Cretaceous beds; (4) the possible absence of younger Paleozoic rocks in the western part of the state; (5) the apparent lack of well developed reservoir rocks above the Knox dolomite group in the middle section; (6) the inconsistency and rapid decline of shallow Ordovician production; and (7) the restriction of present Mississippian and Ordovician production to small structures.

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VOL. 25, NO. 8 (AUGUST, 1941), PP. 1587–1597, 4 FIGS.

GEOLOGICAL NOTES

OIL-FIELD MODELS OF SHREVEPORT GEOLOGICAL SOCIETY[1]

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Denver, Colorado

The excellent work of the Shreveport Geological Society in publicizing geology in Louisiana and vicinity merits commendation and publicizing itself. The photographs herein are of oil-field models planned and supervised by the Society and made by employees of the

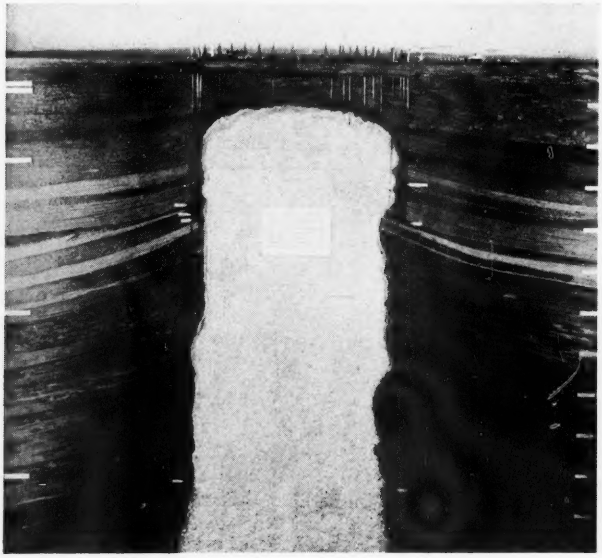


FIG. 1.—Model of a South Louisiana salt dome. Size: 5×6 feet.

State Agricultural Department. The models are part of the oil and gas industries display in the Louisiana State Exhibit Building at Shreveport, a building devoted to the permanent exhibit of the natural resources of Louisiana under the management of the Louisiana Department of Agriculture. The vertical and horizontal scales of the models are 1 inch equals 300 feet.

[1] Manuscript received, May 1, 1941.

[2] United States Geological Survey; chairman, Association committee on applications of geology.

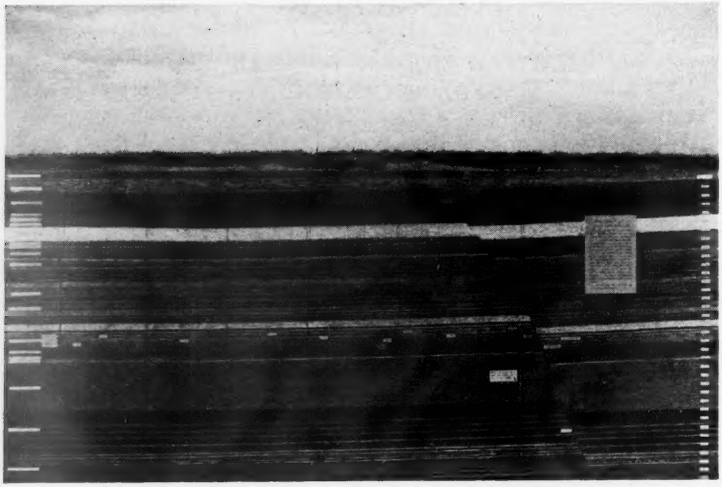


FIG. 2.—Model of Rodessa oil field, Louisiana and Texas, a faulted type of oil structure. Size: 8×6 feet.

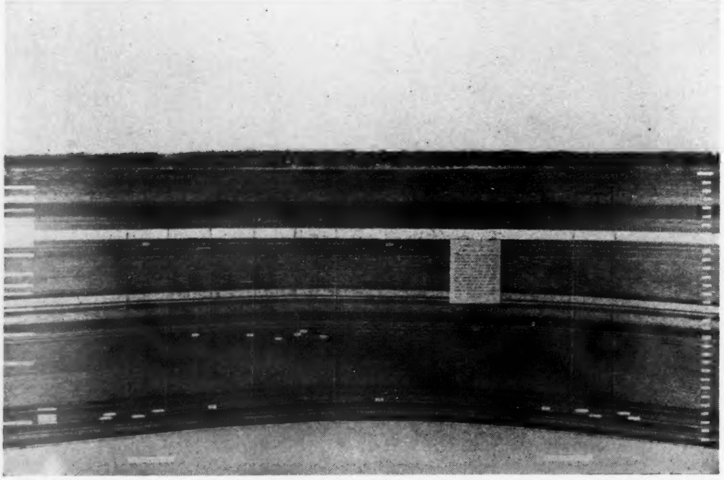


FIG. 3.—Model of Cotton Valley oil field, Louisiana, a domal type of oil structure. Size: 8×6 feet.

In addition to the models pictured herein, the Shreveport Geological Society has had prepared for showing in the exhibit building a model of a drilling rig and equipment, one showing the relationships between tanks, separators, and lines in an oil field, and another explaining the refining of petroleum.

RELATION OF INITIAL PRODUCTION TO ULTIMATE PRODUCTION OF WELLS COMPLETED IN SMITHWICK (GRAY) LIMESTONE, BRECKENRIDGE FIELD, STEPHENS COUNTY, TEXAS[1]

DAVID DONOGHUE[2]
Fort Worth, Texas

This study is an analysis of individual well-recovery data on 79 wells completed by one operator in the Smithwick (Gray) limestone of Pennsylvanian age, in the Breckenridge field, Stephens County, Texas.

The Smithwick (Gray) limestone has been variously called "brown lime," "white lime," and "Breckenridge lime" to differentiate it from its stratigraphic equivalent, the Caddo (Black) limestone of the Necessity-Caddo area.

This study includes all the wells drilled by the one operator in the Breckenridge field, excepting: several wells on which full information was not readily available, or which produced oil in very small quantities; one well which was "exceptional" in that it had a relatively small initial production and a relatively large recovery; and one well (the second largest, if the writer remembers correctly, in Stephens County) which, while reasonably "normal" in the initial-ultimate relationship, produced figures too large to plot conveniently on the chart (Fig. 1).

The wells were completed during and between the years 1918 and 1926; the greater number of them were completed during the Ranger boom of 1918–1921.

Completion and production practices were not the "efficient" methods used to-day. The wells were drilled with cable tools; some were shot with nitroglycerine, and were produced to full capacity. At some wells several days or weeks would elapse between the beginning of production and the final completion by drilling to the total depth or by shooting.

[1] Manuscript received, May 22, 1941.

[2] Consulting geologist, 1306 Fort Worth National Bank Building.

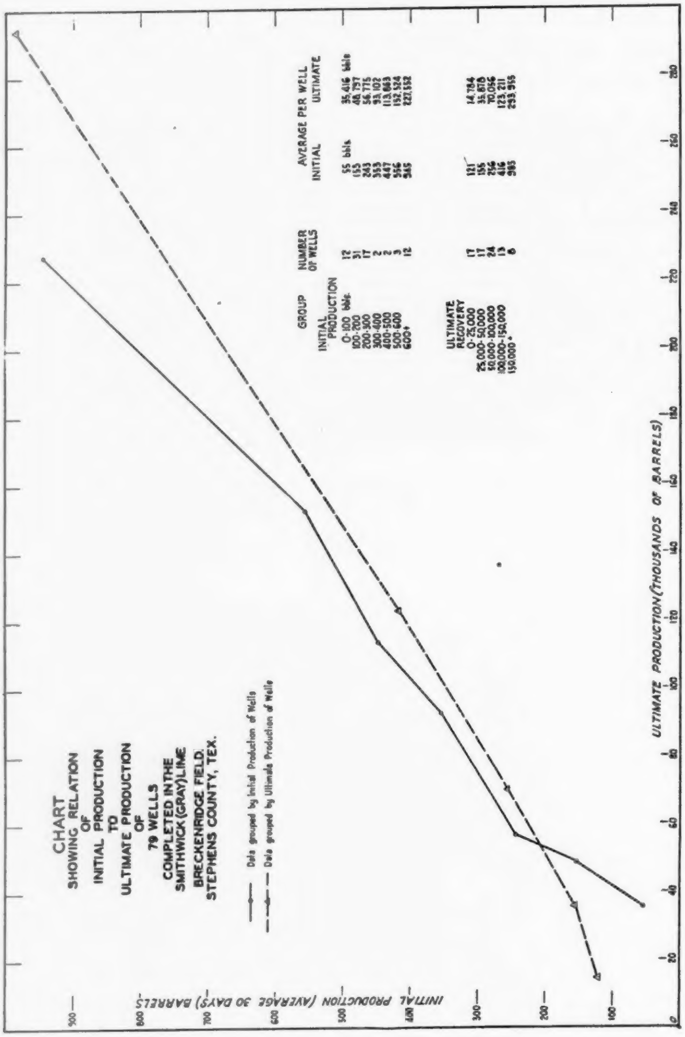


CHART
SHOWING RELATION
OF
INITIAL PRODUCTION
TO
ULTIMATE PRODUCTION
OF
79 WELLS
COMPLETED IN THE
SMITHWICK (GRAY) LIME
BRECKENRIDGE FIELD,
STEPHENS COUNTY, TEX.
Data grouped by Initial Production of Wells
Data grouped by Ultimate Production of Wells
GROUP
NUMBER OF WELLS
AVERAGE PER WELL
INITIAL
ULTIMATE
INITIAL PRODUCTION
0-100 bbls. 12 55 bbls 35,416 bbls
100-200 31 155 48,757
200-300 17 243 56,775
300-400 2 353 93,102
400-500 2 447 113,063
500-600 3 556 152,524
600+ 12 945 227,552
ULTIMATE RECOVERY
0-25,000 17 121 14,784
25,000-50,000 17 155 35,676
50,000-100,000 24 256 70,056
100,000-150,000 13 416 123,211
150,000+ 6 985 293,955
INITIAL PRODUCTION (AVERAGE 30 DAYS) BARRELS
ULTIMATE PRODUCTION (THOUSANDS OF BARRELS)

FIG. 1

Well spacing was generally on a 10-acre basis. The depths of the wells were approximately 3,100–3,200 feet.

As at January 1, 1941, 38 of these wells were producing and 41 had been abandoned. The 38 producing wells made 60,664 barrels of oil during the year 1940, an average of 4.3 barrels per well per day. The two best wells each made approximately 14 barrels of oil per day during the year 1940. In December, 1940, these wells produced daily 136 barrels of oil and 533 barrels of water. It is the writer's opinion that these wells have long since passed the economic limit of production as producers of oil. Gas sales probably account for their continued operation. Acidization during the years 1933–1935 substantially increased recoveries.

The initial production used is that actually shown by daily well gages, averaged over the first 30 days, or when such gages were not available, an average of the well production during the first 2 calendar months. For some wells the best month's average of the first several months' production was used.

The wells were classified into groups of similar initial production, averages were made of the initials and ultimates of each group, and a curve was plotted. The wells were also classified into groups of similar ultimate production, and were averaged and plotted.

The evident straight-line relationship between initial production and ultimate production, as shown on the chart, indicates that the relationship is a fundamental index of reservoir quality and quantity.

Quality of experience and detailed information are other factors that make the relationship a tool applicable to various problems of the industry. It has always been considered that the ability of a well to produce is an index of its value.

A similar initial-ultimate relationship has been observed by E. H. Griswold and E. A. Wahlstrom in the Church-Fields area, Crane County, Texas, in the Westbrook field, Mitchell County, Texas, and in the Big Lake field (3,000-foot Permian limestone), Reagan County, Texas. A paper is being prepared on the subject.

MEMORIAL SHALE OF PENNSYLVANIAN AGE, IN OKLAHOMA[1]

ROBERT H. DOTT[2]
Norman, Oklahoma

The term Memorial shale was first applied by the writer, in 1935, in an unpublished manuscript, to beds of the upper Des Moines series

[1] Manuscript received, May 23, 1941.

[2] Director, Oklahoma Geological Survey.

cropping out in Tulsa County and vicinity. They lie above the Lenapah (Eleventh Street) limestone, and below the Seminole formation. The term Memorial shale has never been formally defined in print, but has come into usage in informal discussion; in publications of the State Geological Survey of Kansas;[3] and will be discussed in detail in a bulletin on Tulsa County, by Malcolm C. Oakes, to be published by the Oklahoma Geological Survey.

For these reasons it seems advisable at this time to offer a formal definition of the term; a review of the history of nomenclature applied to these and associated strata; and a brief discussion of the distribution, character, thickness, stratigraphic relations, age, and correlation of the strata to which the term is applied.

Type locality.—The Memorial shale is named from Memorial Park Cemetery. It may be seen about $\frac{3}{4}$ mile south of the cemetery entrance, where the lower part is exposed in the road cut, along the east line of the SE. $\frac{1}{4}$ of Sec. 35, T. 19 N., R. 13 E., and the upper part extends up the slope of a prominent "mound" in the SE. $\frac{1}{4}$ of Sec. 35, which is capped by the basal beds of the overlying Seminole formation.

A better and almost complete exposure may be seen in road cuts in the half-mile east of the intersection of East Eleventh Street (U. S. Highway 66) and Sheridan Road, and in gullies in the SW. $\frac{1}{4}$ of Sec. 2, and this is offered as the type section.

The basal part of the Memorial shale can be studied better in road cuts south of Memorial Park, and the upper part including the contact with the overlying Seminole formation, in the road cuts along Eleventh Street, east of Sheridan Road.

Definition.—The term Memorial shale is applied to the strata above the top of the Lenapah (Eleventh Street) limestone, and below the base of the Seminole formation. In the latitude of Tulsa it consists principally of clay shale with silty streaks and contains, near the middle, about 10 feet of sandstone in thin, fine-grained to silty beds a few inches thick, interspersed with sandy, silty shale, and locally in the upper part, one or more thin fossiliferous limestone beds a few inches thick.

History.—The importance of the stratigraphic unit here called Memorial shale was first recognized by Ronald J. Cullen and the writer in 1933, while working on a field project of the Tulsa Strati-

[3] R. C. Moore, "Stratigraphic Classification of the Pennsylvanian Rocks of Kansas," *State Geol. Survey of Kansas Bull. 22* (1936), p. 67.

John M. Jewett, "Oil and Gas in Linn County, Kansas," *ibid., Bull. 30* (1940), p. 24.

G. E. Abernathy, "Oil and Gas in Montgomery County, Kansas," *ibid., Bull. 31* (1940), p. 19.

graphic Society, and by Norman D. Newell, in connection with a study of the Pennsylvanian of the northern Mid-Continent, a project of the Geological Society of America.

The unit was formerly considered a part of the Nowata shale, which, by definition, is limited at the top by the Lenapah limestone, but was erroneously extended upward, in the vicinity of Tulsa, to include beds as high as the base of the Dawson coal.[4] The proper understanding of the significance of the Memorial shale involves a review of past usage of terms applied to the upper Des Moines, and lower Missouri beds of northeastern Oklahoma.

In the northern part of the area, Ohern[5] originally named, among others, the following units, in ascending order: Oologah formation, composed of the Pawnee limestone, Bandera shale, and Altamont limestone; Nowata shale; Lenapah limestone; and Curl formation, a term that has subsequently been dropped in favor of Coffeyville formation.[6]

The history of subsequent usage is summarized by Oakes.[7]

During the course of field work, Cullen and the writer determined that the Seminole formation is incorrectly shown on the "Geologic Map of Oklahoma," between Beggs and the north line of Okmulgee County (middle of T. 16 N., R. 12 E.); that it lies somewhat farther west than mapped; that the Seminole is continuous with sandstones that underlie the city of Tulsa, and extend eastward to Sheridan Road; that it contains the Dawson coal in its middle part; and that it can be traced northward to the Kansas line. It was further determined that the base of the Seminole formation marks the boundary between the Des Moines and overlying Missouri series.

The same workers also reached the conclusion that the Eleventh Street limestone[8] is equivalent to the Lenapah limestone of the northern area, and decided that the term "Eleventh Street" should be

[4] D. W. Ohern, discussion of paper by Frank C. Greene, "A Contribution to the Geology of Eastern Osage County," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 2 (1918), p. 122.
H. D. Miser, "Geologic Map of Oklahoma," *U. S. Geol. Survey* (1926).

[5] D. W. Ohern, "The Stratigraphy of the Older Pennsylvanian Rocks of Northeastern Oklahoma," *Univ. Oklahoma Research Bull. 4* (1910).

[6] H. D. Miser, *op. cit.*
Malcolm C. Oakes, "Geology and Mineral Resources of Washington County, Oklahoma," *Oklahoma Geol. Survey Bull. 62* (1940), pp. 34–35.

[7] Malcolm C. Oakes, *op. cit.*

[8] Name previously proposed informally by Frank C. Greene, for a coquinoid limestone cropping out on East Eleventh Street (U. S. Highway 66), about ½ mile east of the intersection of East Eleventh Street and Sheridan Road, NE. ¼ of Sec. 11, T. 19 N., R. 13 E.

dropped in favor of Lenapah. Hence, the term "Nowata shale" of the Tulsa area was restricted to the true meaning of the term, by the elimination of all strata between the base of the Lenapah (Eleventh Street) limestone and the base of the Dawson coal, namely: the Lenapah limestone, the overlying shale of Des Moines age (here named Memorial), and the lower part of the Seminole formation of lower Missouri age. The Coffeyville formation was subsequently restricted by the elimination of the upper part of the Seminole formation, and the Checkerboard limestone.[9]

Distribution.—The Memorial shale has been recognized from the vicinity of Beggs, northwestern Okmulgee County, to Oklahoma State Highway 20, southeast of Collinsville, whence it probably extends somewhat farther northeast. It is definitely absent in the hill just west of the town of Oologah, but was found by Oakes in one exposure, probably the northernmost, along the south line of the SW. $\frac{1}{4}$ of Sec. 33, T. 24 N., R. 15 E., 4 miles north of Oologah. It has been reported in Kansas by Moore,[10] and more recently by Jewett.[11]

South of Beggs, the Lenapah limestone has not been recognized, and the extension of the Memorial shale, as a valid formational unit, from that area to the Arbuckle Mountains, has not been established.

Character.—The Memorial is dominantly shale, but contains some sandstone and limestone. In the area north of Arkansas River, eastern Tulsa County, it is mostly blue clay-shale to sandy shale. It contains a zone of thin-bedded, fine-grained to silty sandstone, near the middle; and at least locally, in the upper part, one or more thin, fossiliferous limestone beds a few inches thick.

South of Arkansas River, especially in the area between Mounds and Beggs, a sandstone (probably the same) lies near the middle of the unit. Locally this sandstone becomes rather massive, and is erroneously shown as Seminole on the "Geologic Map of Oklahoma." In the same area, the upper half of the formation, above the sandstone, contains a series of thin, platy, or flaggy limestones, interbedded in calcareous shale, overlain by a thin coquinoid limestone, similar to the Lenapah (Eleventh Street) limestone of the Tulsa area.

This similarity was the source of considerable confusion while working in this area, for the Lenapah is likewise underlain by calcareous shale containing thin, flaggy limestones, in the upper part of the Nowata shale.

Nearer Beggs, the thin, flaggy limestones are less conspicuous, but the middle sandstone caps the prominent escarpment in the west part

[9] See Malcolm C. Oakes, *op. cit.*, p. 36.

[10] R. C. Moore, *op. cit.*

[11] John M. Jewett, *op. cit.*, and letter dated March 8, 1941.

of town, and the coquinoid limestone in the upper part of the Memorial is well exposed near the NW. cor. of Sec. 19, T. 15 N., R. 12 E., northwest of Beggs, where it is sandy, a foot or more thick, and contains many well preserved forms of *Myalina*, *Linoproductus*, and other forms.

Thickness.—Sections measured by Malcolm C. Oakes show the Memorial shale to be 80 feet thick, in the type area, and 70 feet thick along U. S. Highway 66, east of Sheridan Road. Details of the two sections follow.

SECTION OF MEMORIAL SHALE NEAR MEMORIAL PARK CEMETERY
(SE. ¼ of Sec. 35, T. 19 N., R. 13 E.)

Bed No.	*Character*	*Feet*
Missouri series		
Seminole formation		
12	Covered, probably thin-bedded sandstone on top of hill	10.0
11	Bench, seems to be massive sandstone, about	3.0
	Disconformity	
Des Moines series		
Memorial shale		
10	Covered, probably shale	40.0
9	Bench, probably sandy shale or thin-bedded sandstone	5.0
8	Covered, probably shale	35.0
	Total	80.0
Lenapah limestone		
7	Silty limestone or limy siltstone	1.0
6	Shale, exposed in road cut, contains thin, lenticular, coquinoid limestone	8.0
5	Covered, probably shale	17.0
4	Limestone, reddish brown, crinoidal, exposed west of road	1.5
	Total	17.5
Nowata shale		
3	Covered, probably shale	5.0
2	Shale and limestone flags, not well exposed	20.0
1	Shale, not measured	

SECTION OF MEMORIAL SHALE ALONG U. S. HIGHWAY 66, EAST OF SHERIDAN ROAD
(SW. ¼ of Sec. 2, T. 19 N., R. 13 E.)
(Type Section)

Bed No.	*Character*	*Feet*
Missouri series		
Seminole formation		
12	Sandstone, lower Seminole, irregular base, not measured	
	Disconformity	
Des Moines series		
Memorial shale		
11	Shale, clay-shale with silty and limonitic streaks	10.0
10	Limestone, dark, crinoidal, ferruginous, weathers yellowish brown	0.2
9	Shale, clay-shale, dark, with silty and limonitic streaks	18.0
8	Sandstone in thin, fine-grained to silty beds, a few inches thick, interspersed with sandy, silty shale	10.0
7	Shale, dark, clay-shale, with a few silty, sandy streaks	32.0
	Total	70.2

Lenapah limestone		
6	Limestone, hard, brown, fossiliferous, "fucoidal" around top	1.5
5	Shale, dark, calcareous, weathers gray	2.5
4	Limestone, gray, nodular, fossiliferous	0.2
3	Shale, clay-shale, dark, weathers gray	3.0
2	Limestone, weathers earthy and brown	1.0
	Total	8.2
Nowata shale		
1	Shale, probably dark when fresh, weathers gray, not measured	

Stratigraphic relations.—The Memorial shale is underlain conformably by the Lenapah (Eleventh Street) limestone, and overlain unconformably by the Seminole formation.

In the area under discussion, the Lenapah is a sequence of impure, usually thin limestones, and interbedded shale, and if the uppermost limestone is locally absent, the base of the Memorial may merge with shale of the Lenapah. The most conspicuous feature of the Lenapah is coquinoid limestone, which is 1–2 feet thick in the type area, but thickens to more than 5 feet in the northwest part of T. 18 N., R. 13 E., and to 10 feet or more in the southwest corner of the same township, west of Arkansas River.

Outcrops of the Lenapah are fairly continuous in the area southeast of Tulsa, but are difficult to find northeast of Tulsa. One outcrop may be seen at the E. ¼ cor. of Sec. 23, T. 20 N., R. 13 E., and another in the south road ditch along Oklahoma State Highway 20, about 0.3 miles east of the SW. cor. of Sec. 1, T. 21 N., R. 14 E.

As already mentioned, the Lenapah is absent in the hill west of Oologah, but was observed by Oakes along the south line of the SW. ¼ of Sec. 33, T. 24 N., R. 15 E., where it is overlain by about 10 feet of Memorial shale. It crops out locally from there to Nowata, and thence continuously to the Kansas-Oklahoma line.

The upper contact of the Memorial shale with the overlying Seminole formation is one of unconformity. From Beggs to the vicinity of Collinsville, it is marked by change from clay-shale or sandy shale, to coarse sandstone, with local depositional irregularities and channeling. Truncation at the top of the Memorial is shown between the two measured sections previously given. Between Collinsville and Oolagah, both the Memorial shale and the Lenapah limestone are completely truncated, and the basal Seminole sandstone overlaps onto the Nowata shale, but part of the Memorial, and the Lenapah, are present in one exposure 4 miles north of Oologah.

Northward from the latitude of Talala, the lower Seminole sandstone is overlapped by the middle shale, so that the Dawson coal lies only a few feet above the Lenapah limestone, and the Memorial shale

is probably absent northward to the Kansas line. In T. 28 N., R. 16 E., the Dawson coal disappears, but the upper Seminole sandstone, though much reduced in thickness, persists into Kansas.

Age and correlation.—The Memorial shale is equivalent to the upper part of the Holdenville shale, of south-central Oklahoma, and to strata formerly mapped as upper Nowata shale, in the vicinity of Tulsa. Shale in the same position above the Lenapah, and below the Seminole, and containing Des Moines fossils, has been called Memorial in Kansas.[12]

Fossils of the Memorial have not been studied carefully. The diagnostic Des Moines genera *Prismopora* and *Mesolobus* are common in the Lenapah limestone, both in the northern area, and near Tulsa. *Mesolobus* was also found in the uppermost part of the Holdenville, a few feet below the base of the Seminole, in beds probably equivalent to the Memorial, near the town of Nuyaka, in the NW. $\frac{1}{4}$ of Sec. 27, T. 14 N, R. 11 E., indicating that the Memorial is Des Moines in age. The regional unconformity at the base of the Seminole suggests it as a logical plane for making a major division, and the Des Moines-Missouri boundary is drawn there.

[12] R. C. Moore, *op. cit.*
J. M. Jewett, *op. cit.*
G. E. Abernathy, *op. cit.*

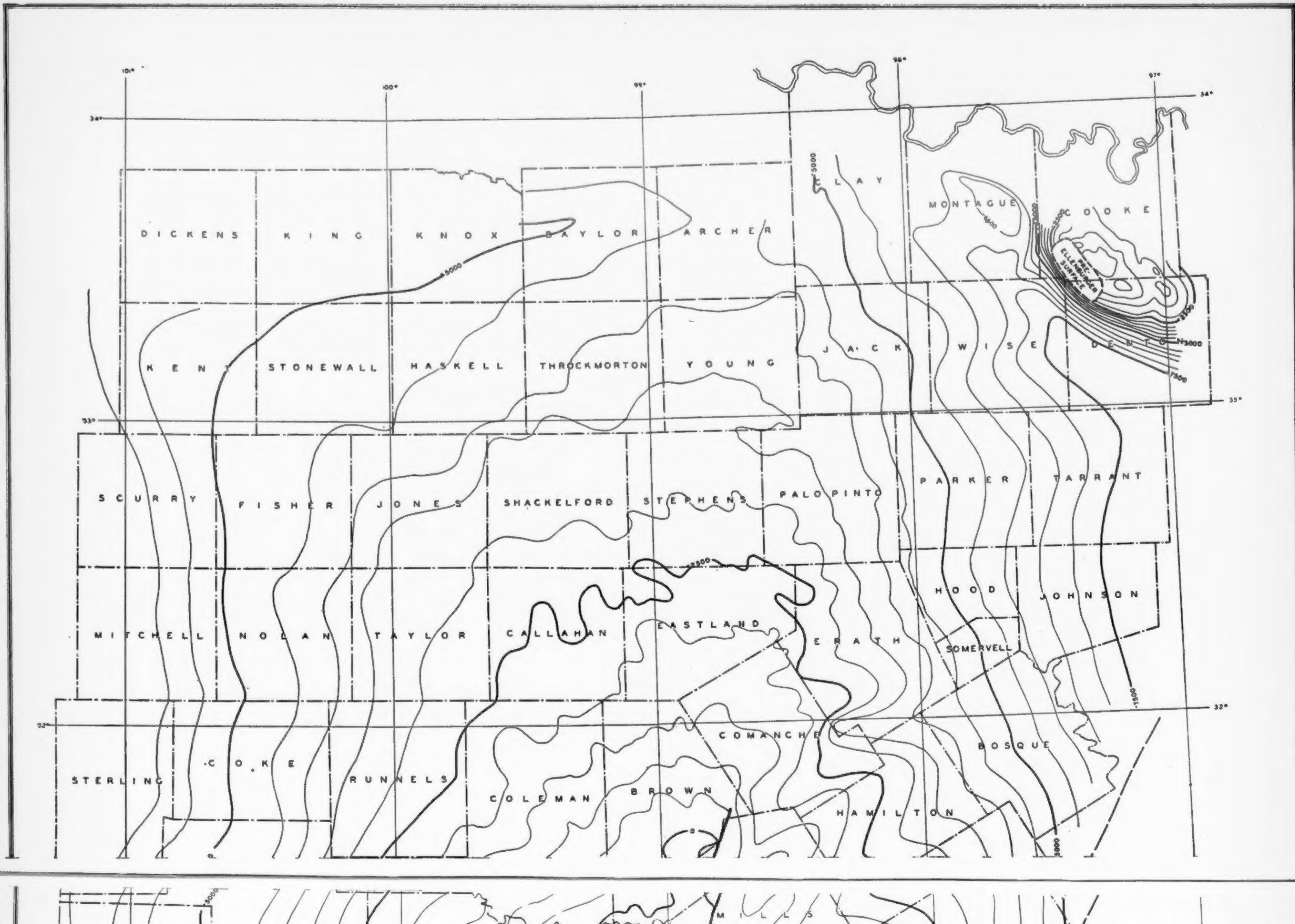
CORRECTION

GEOLOGY OF EOLA OIL FIELD, AVOYELLES PARISH, LOUISIANA

In the article, "Geology of Eola Oil Field, Avoyelles Parish, Louisiana," by Fred W. Bates, in the July *Bulletin*, Vol. 25, No. 7, pages 1382 and 1385, the cut lines of Figure 8 and Figure 10 are unfortunately transposed. Figure 8, on page 1382, is a structure-contour map of the Eola field, drawn on the sub-sea top of the Cockfield sand. Figure 10, on page 1385, is a structure-contour map of the Eola field, drawn on the sub-sea top of the Wilcox.

MICROPALEONTOLOGY—PAST AND FUTURE

The second name in the second column of names on page 1230 (July *Bulletin*) should read Professor Charles Schuchert.



PRE-ELLENBURGER SURFACE
DICKENS
KING
KNOX
BAYLOR
ARCHER
CLAY
MONTAGUE
COOKE
KENT
STONEWALL
HASKELL
THROCKMORTON
YOUNG
JACK
WISE
DENTON
SCURRY
FISHER
JONES
SHACKELFORD
STEPHENS
PALO PINTO
PARKER
TARRANT
MITCHELL
NOLAN
TAYLOR
CALLAHAN
EASTLAND
ERATH
HOOD
JOHNSON
SOMERVELL
STERLING
COKE
RUNNELS
COLEMAN
BROWN
COMANCHE
BOSQUE
HAMILTON
MILLS
101°
100°
99°
98°
97°
34°
33°
32°
5000
7500
2500

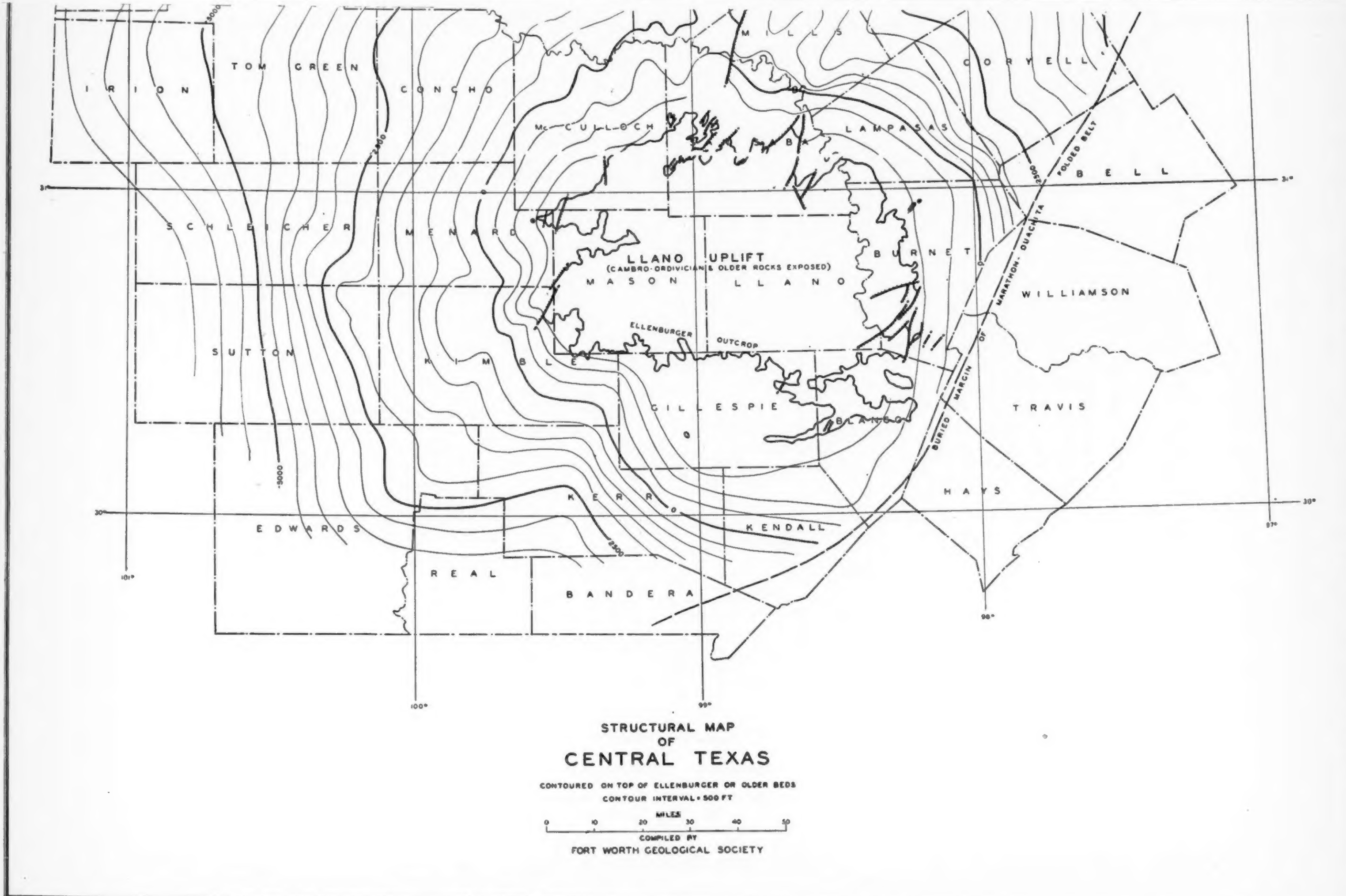

STRUCTURAL MAP
OF
CENTRAL TEXAS
CONTOURED ON TOP OF ELLENBURGER OR OLDER BEDS
CONTOUR INTERVAL = 500 FT
MILES
0 10 20 30 40 50
COMPILED BY
FORT WORTH GEOLOGICAL SOCIETY
LLANO UPLIFT
(CAMBRO-ORDIVICIAN & OLDER ROCKS EXPOSED)
ELLENBURGER OUTCROP
BURIED MARGIN OF MARATHON - OUACHITA FOLDED BELT
IRION
TOM GREEN
CONCHO
McCULLOCH
MILLS
CORYELL
LAMPASAS
BELL
SCHLEICHER
MENARD
MASON
LLANO
BURNET
WILLIAMSON
SUTTON
KIMBLE
GILLESPIE
BLANCO
TRAVIS
HAYS
EDWARDS
KERR
KENDALL
REAL
BANDERA
31°
30°
101°
100°
99°
98°
97°
-5000
-2500
0

Fig. 1

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 25, NO. 8 (AUGUST, 1941), P. 1600 (1 FIG. ON PP. 1598-1599)

RESEARCH NOTES

ELLENBURGER STRUCTURE MAP OF CENTRAL TEXAS[1]

A. I. LEVORSEN[2]
Tulsa, Oklahoma

The tectonic committee of the Division of Geology and Geography of the National Research Council has been preparing a tectonic map of the United States for the past 6 years. A preliminary map was printed last year and copies sent to the various geological societies, for corrections, comments and changes which would be embodied in the final map. The Fort Worth Geological Society, with many others, responded generously to the request. They prepared an entirely new map of the area from the Llano uplift on the south to the Red River on the north, contoured on the upper surface of the Ellenburger limestone, Cambro-Ordovician age. Inasmuch as it may be some time before the final tectonic map is printed, and because of the excellent work this society has done, it was thought that its publication in advance of the final assembly would be of interest to the Association. See map on pp. 1598–1599.

The contours shown are on the top of the Ellenburger "or older beds" for the reason that in some parts of the area the upper Ellenburger is absent either because of non-deposition or erosion. Faulting in the Ellenburger in the subsurface is shown only where the data seemed to indicate there was no other interpretation. Thus, many faults which have previously been shown in parts of this area are not indicated on the present map. Also, since there is much new surface mapping in progress in the Llano-Burnet area, no attempt is made to show the detail of the faulting inside the older outcrop area. The southwest flank of the Muenster arch in Cooke County is shown by closely spaced contours but with additional information it may be proved to be faulting in whole or in part.

The position of the Cretaceous overlap has been omitted as it is not considered important in an Ellenburger map. The well known surface *en échelon* faults in Throckmorton County have also been omitted as there is no indication as yet that they continue down to the lower beds or that there is any local disturbance with depth.

[1] Manuscript received, June 4, 1941.

[2] Chairman, research committee. 221 Woodward Boulevard.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 25, NO. 8 (AUGUST, 1941), PP. 1601-1604

REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and available, for loan, to members and associates.

THE UPPER CRETACEOUS DEPOSITS IN MISSISSIPPI, BY LLOYD WILLIAM STEPHENSON AND WATSON HINER MONROE

REVIEW BY HENRY N. TOLER[1]
Jackson, Mississippi

"The Upper Cretaceous Deposits in Mississippi," by Lloyd William Stephenson and Watson Hiner Monroe. *Mississippi State Geol. Survey Bull. 40* (University, Mississippi, 1940). 296 pp., 6×9 inches, including 15 pls. and 48 figs.

This bulletin is based on field investigation by Stephenson over a period of years and more recent surface work by Monroe. The area covered is located in northeast Mississippi and is 50 miles in width and 160 miles in length.

Stratigraphy occupies the greater part of the bulletin and the discussion and description of the various formations are limited to outcrops, no attempt being made to cover these in the subsurface. Following the abstract is a review of the former work and literature about the Cretaceous deposits in Mississippi. A list of 66 references is given. The physiography of the area is next discussed. Following the physiography one page is devoted to structure. In the northern third of the area the strike of the beds is N. 15° E. Farther south the strike curves southeast and at the Alabama-Mississippi line it is N. 30° W. The dip varies, but averages 25 feet per mile toward the west-southwest into the Mississippi embayment. One anticline in Lowndes County is mentioned and several small faults are noted in five of the counties. Time was not available to study all structural details.

The various formations are described and discussed in considerable detail. In ascending order they are the Tuscaloosa formation; the Eutaw formation, including the Tombigbee sand member at the top; the Selma chalk and its partial equivalents, the Coffee sand and the Ripley formation; and the Prairie Bluff chalk and its equivalent, the Owl Creek formation.

Fifteen to 48 pages are used in describing each of these formations or units and they are discussed as to the derivation of name, distribution, lithologic character and thickness, stratigraphic and age relation. There is an excellent discussion of the macroscopic fossils of each formation with localities given and a chart naming the fossils and giving their distribution. The more diagnostic of these fossils are shown by a series of photographic plates. The formations are then treated by counties, with a number of excellent exposures and sections described in detail. There are many good photographs of exposures of the various formations.

Several changes in the classification of the deposits have been made since publication in 1928 of the geologic map of Mississippi. The principal ones are the recognition of the Coffee sand as a unit of formation rank, the raising of the Prairie Bluff chalk to the rank of a distinct formation and the abandoning

[1] Southern Natural Gas Company. Manuscript received, May 31, 1941.

of the name Oktibbeha tongue, the differentiation of the Owl Creek as a formation distinct from the Ripley, and the definition of the Arcola limestone member of the Selma.

Erosion intervals at the top of the Tuscaloosa, the top of the Eutaw, the top of the Arcola, and the base of the Prairie Bluff-Owl Creek, are pointed out.

Since the completion of the manuscript of this bulletin additional work in Alabama by Monroe has shown the need of two changes in the classification as presented, but it was too late to incorporate the changes in this report. The changes are as follows.

No. 1

Place the 50 feet of sandy chalk between the top of the *Exogyra cancellata* zone and the base of the Prairie Bluff chalk in the Ripley formation and treat it as a facies of that unit.

No. 2

Give the name Demopolis member to the 500 feet of purer facies of Selma chalk between the Arcola limestone member and the top of the *Exogyra cancellata* zone.

Faunal zones in the series are described and the formations are correlated with those to the west in Texas, with those to the northeast along the Atlantic slope and with the standard European section. It is suggested that the Tuscaloosa formation is equvalent to the Woodbine of Texas, with no Eagle Ford present, thus giving considerable erosional interval between the Eutaw and the Tuscaloosa formations. There are some who question that the Tuscaloosa and Woodbine are the same age.

This bulletin is the result of coöperative work between the United States Geological Survey and the Mississippi State Geological Survey. Both of these organizations are to be congratulated on the publication of this timely report. It will be appreciated by all geologists working with the Cretaceous, and particularly by the petroleum geologists who are daily studying and attempting to correlate these formations in the various wells which have been drilled and are being drilled in the search for oil in this area. All production of both oil and gas in Mississippi, with the exception of the small Amory gas field, is from beds of Cretaceous age.

The revision of classification as presented in this bulletin has greatly restricted the name Selma chalk as it has generally been applied and understood. The reviewer wonders if the term Selma might not be retained to cover all beds from the Eutaw to the Midway and that the various units be made members.

RECENT PUBLICATIONS

ALBERTA

*"Preliminary Map, Brazeau, Alberta," by B. R. MacKay. *Canada Geol. Survey Paper 41-4* (Ottawa, 1941). Blue-line paper sheet approx. 28×40 inches. Topographic contour interval, 100 feet. Rocks mapped include formations from Devonian to Upper Cretaceous. A separate sheet, approx. 37×15 inches, shows structural sections on horizontal and vertical scale of 2 inches equals 1 mile.

CALIFORNIA

*"Mesa Oil Field," by S. G. Dolman. *California Oil Fields*, Vol. 24, No. 2 (San Francisco, October, November, December, 1938 [1941]), pp. 5–14; 2 pls. (maps).

*"Capitan Oil Field," by S. G. Dolman. *Ibid.*, pp. 15–26; 6 pls. (maps, sections, chart).

*"Santa Maria Valley Oil Field," by Ralph G. Frame. *Ibid.*, pp. 26–47; 9 pls. (maps, sections, charts).

GENERAL

An Introduction to Physical Geology with Special Reference to North America, by William J. Miller. 4th ed. (1941). 465 pp., 397 figs., frontispiece. 6×9 inches. Cloth, paper jacket. D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York City. Price, net, $3.25.

Field Geology, by Frederic H. Lahee. 4th ed. (1941). 853 pp., 5×7.25 inches, 599 illus. McGraw-Hill Book Company, Inc. Complete manual of geological methods and working data for petroleum and mining engineers and geologists. Price, $5.00.

"Geophysical Abstracts 99, October-December, 1939," compiled by W. Ayvazoglov. *U. S. Geol. Survey Bull. 915-D* (April, 1941), pp. 133–95. Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $0.10.

"Geophysical Abstracts 101, April–June, 1940," *ibid.*, *Bull. 925-B* (April, 1941), pp. 51–92.

**Oil and Gas Field Development in United States*, by National Oil Scouts and Landmen's Association. Vol. XI. Year Book 1941. Annual review, for 1940, of geological and geophysical prospecting, land and leasing activities, wildcat exploration, proved field development, gas and oil production, pipeline and refining statistics. Edited under direction of W. E. Tracy and E. J. Raisch. 664 pp., illus. Cloth. 8×11 inches. National Oil Scouts and Landmen's Association, Austin, Texas (June, 1941). Price, $7.50.

"Petroleum Development and Technology 1941," by the Petroleum Division. *Trans. Amer. Inst. Min. Met. Eng.*, Vol. 142 (New York, 1941). 587 pp., illus. Cloth. 6×9 inches. Papers and discussions presented before the Division at meetings held at New York, February 12–15, 1940; Los Angeles, October 17–18, 1940; Tulsa, October 24–26, 1940; also the petroleum statistical reports covering the year 1940. Published by the Institute, 29 West 39th Street, New York City.

ILLINOIS

**The New Oil Fields of Southern Illinois*, by Don L. Carroll. 30 pp., illus. A separate, illustrating the activity of the Mineral Industries Committee of the Illinois Chamber of Commerce in publicizing and popularizing the natural resources of the state. Published by the Illinois Chamber of Commerce with the coöperation of the Illinois State Geological Survey.

KENTUCKY

"Additions to the Wilcox Flora from Kentucky and Texas," by E. W. Berry. *U. S. Geol. Survey Prof. Paper 193-E* (April, 1941), pp. 83–99, Pls. 20–24. Sold by Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $0.15.

LOUISIANA

*"The Louisiana Geological Survey—Its Work," by J. Huner, Jr. *Oil*, Vol. 1, No. 4 (New Orleans, May, 1941) pp. 25–28, and 50; 11 illus.

MISSOURI

*"Outlines of Missouri Geology," by Charles Keyes. *Pan-Amer. Geol.*, Vol. 75, No. 5 (Des Moines, Iowa, June, 1941), pp. 337–66; 8 illus., chart of formations.

TEXAS

"Additions to the Wilcox Flora from Kentucky and Texas," by E. W. Berry. *U. S. Geol. Survey Prof. Paper 193-E* (April, 1941), pp. 83–99; Pls. 20–24. Sold by Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $0.15.

"Geology and Ground-Water Resources of the Lufkin Area, Texas," by W. N. White, A. N. Sayre, and J. F. Heuser. *U. S. Geol. Survey Water-Supply Paper 849-A* (April, 1941). 58 pp., 2 pls., 2 figs. Sold by Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $0.30.

*"Abell Field, Northern Pecos County, West Texas," compiled by *Oil and Gas Jour.*, Vol. 40, No. 6 (Tulsa, June 19, 1941), pp. 28–29; 1 development map.

*"North Texas," *ibid.*, Vol. 40, No. 7 (June 26, 1941), pp. 50–51; geological map and type-stratigraphic sections in colors.

TURKEY

*"Lignites and Bituminous Schists of the Sakarya River Basin," by V. Stchepensky. *Maden Tetkik Arama Enstit. Mecmuasi*, Sene 6, Sayi 1–22 (Ankara, 1941), pp. 9–22 (in Turkish), pp. 23–36 (in French), 6 photographs, 1 map.

WEST VIRGINIA

*"West Virginia," compiled by *Oil and Gas Journal*, Vol. 40, No. 5 (Tulsa, June 12, 1941), pp. 54–55; geologic map and stratigraphic log sections in colors.

WYOMING

"Petroleum and Natural Gas Fields in Wyoming," by Ralph H. Espach and H. Dale Nichols. *U. S. Bur. Mines Bull. 418.* 185 pp. 72 illus. Appendix contains 104 oil analyses, 66 gas analyses, 62 water analyses, tables of oil and gas production, *et cetera.* Prepared in coöperation with the U. S. Geological Survey and the University of Wyoming. Sold by Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $2.25. Descriptive announcement in *U. S. Bur. Mines P. N. 147034* (June 17, 1941), 4 mim. pp.

*"Asphalts from Some Wyoming and Other Asphalt-Bearing Crude Oils," by K. E. Stanfield. *U. S. Bur. Mines R. I. 3568* (May, 1941). 53 mim. pp., 16 figs.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 25, NO. 8 (AUGUST, 1941), PP. 1605-1609, 3 FIGS.

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

Ervin A. Brecke, Rosiclare, Ill.
W. A. Clark, Jr., Howard C. Warren, R. J. St. Germain
Vellora M. Foster, University, Miss.
V. T. Stringfield, Frederic Mellen, Watson H. Monroe
Lois T. Martin, Stanford University, Calif.
Hubert G. Schenck, Stanley G. Wissler, Robert T. White
Maynard Moody Stephens, Bradford, Pa.
Sylvain J. Pirson, W. H. Emmons, Clinton R. Stauffer

FOR ASSOCIATE MEMBERSHIP

Eugene Borax, Los Angeles, Calif.
James Gilluly, M. N. Bramlette, U. S. Grant
Robert Ewell Bush, Houston, Tex.
Fred E. Smith, R. D. Woods, E. E. Rosaire
Theodore Scott Childs, Jr., Riverside, Calif.
Hubert G. Schenck, A. C. Waters, Eliot Blackwelder
James Ryder Chilton, Claresholm, Alta., Canada
V. E. Monnett, Charles E. Decker, C. G. Lalicker
John J. Collier, Jr., Dallas, Tex. (Houston Geological Society Student Award)
F. E. Turner, Lyman Toulmin, Jr., Charles S. Bacon, Jr.
John Chambers Crowell, Claremont, Calif.
James Gilluly, Cordell Durrell, E. K. Soper
Steven Norman Daviess, Los Angeles, Calif.
M. N. Bramlette, James Gilluly, U. S. Grant
Max Everett Ferrell, Clarksburg, W. Va.
William W. Mayfield, E. H. Tollefson, E. B. Branson
James Helis, New Orleans, La.
W. C. Bednar, C. G. Lalicker, C. K. Moresi
William Bayard Heroy, Jr., Princeton, N. J.
W. T. Thom, Jr., J. B. Knight, Steven K. Fox
Floyd Phillip Hurry, Oklahoma City, Okla.
R. W. Harris, V. E. Monnett, Charles E. Decker
William G. Iversen, Hemingford, Nebr.
A. L. Lugn, E. F. Schramm, E. C. Reed
Robert Bowen Kelly, Glendale, Calif.
R. Ten Eyck, R. M. Barnes, Glenn H. Bowes
James Edward Lewark, Pleasant Hill, Ill.
M. W. Fuller, E. R. Branson, B. H. Richards, Jr.

Wilbur Earl McMurtry, Wichita, Kan.
V. E. Monnett, C. G. Lalicker, Charles E. Decker
Frank Morrow Pool, Waco, Tex. (Houston Geological Society Student Award)
Charles S. Bacon, Jr., Harold Vance, Henry Emmett Gross
John Walter Reiss, Corpus Christi, Tex.
Fred M. Bullard, Robert H. Cuyler, Hal P. Bybee
Margaret Alice Tribble, Bartlesville, Okla.
V. E. Monnett, C. G. Lalicker, Charles E. Decker
Joyce Irene Waters, Houston, Tex.
Warren O. Thompson, J. Harlan Johnson, Harry W. Oborne
Philip Anthony Williams, Tulsa, Okla.
D. L. Blackstone, Jr., Paul H. Umbach, R. S. Poor

FOR TRANSFER TO ACTIVE MEMBERSHIP

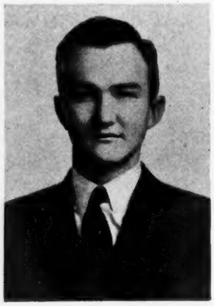
Garth William Caylor, Evansville, Ind.
Charles E. Decker, L. M. Clark, J. R. McGehee
Paul Hugus Jamison, Jr., Altamont, Ill.
C. L. Bartlett, C. B. Claypool, A. P. Allison
Harry J. McCready, Jr., Denver, Colo.
Walton Sumner, E. A. McCullough, D. A. McNaughton
Maynard Rogers, Evansville, Ind.
Harold M. Horton, Kenneth L. Gow, Paul F. Osborne
G. P. Salas, Tampico, Tamps., Mex.
Ezequiel Ordoñez, Manuel Alvarez, Jr., W. G. Green

HOUSTON GEOLOGICAL SOCIETY STUDENT AWARDS

The Houston Geological Society of Houston, Texas, held its second annual student award program on May 16, 1941. The award consists of a 2-year paid-up associate membership in the American Association of Petroleum Geologists. The award is given to one member of the geology department and to one member of the petroleum engineering department of the Agricultural and Mechanical College of Texas. Selection of honorees is made by the Houston Society from papers presented at the award program.

The two students selected for the 1941 award are Frank M. Pool, who presented a paper on the "Uses and Limitations of Cement as a Means of

JOHN J. COLLIER, JR.



FRANK M. POOL

Shutting Off Bottom-Hole Water," and John J. Collier, Jr., whose paper was entitled the "Texas Drainage System."

JOHN J. COLLIER, JR., B. S. (geology, 58 hours), June, 1941, Agricultural and Mechanical College of Texas, College Station, Texas (1938-41). Born, June 15, 1918, Chicago, Illinois. Preparatory: Sunset High School, Dallas, Texas (1931-34); Technical High School Dallas (1934-35); North Texas Agricultural College, Arlington (1936-38). Experience: 1937-40 (summers) water department of Dallas; 1938, assistant in biology department at N.T.A.C.; 1939-41, worked for geology department at A. and M. Member: A. & M. Geology Club, Phi Kappa Theta local scholarship honor society at N. T. A. C.

FRANK M. POOL, B. Petroleum Eng. (geology, 18 hours), 5-year course, June, 1941, Agricultural and Mechanical College of Texas, College Station, Texas (1936-41). Born, August 29, 1918, Grandview, Texas. Preparatory: Waco High School, Waco. Experience: 1940, student assistant in the petroleum department; 1941, student assistant in junior petroleum production laboratory; 1940 (summer) roustabout, Humble Oil and Refining Company. Holds commission as a 2d lieutenant in the Cavalry Reserves. Has accepted employment with the Humble Oil and Refining Company.

SOUTH TEXAS GEOLOGICAL SOCIETY STUDENT AWARD

The second annual student award meeting of the South Texas Geological Society was held at the Menger Hotel in San Antonio on the evening of May 16, 1941. Subjects had been submitted to senior students in geology at the University of Texas and eight men had participated in preliminary papers before the faculty and geological department at Austin. The four finalists who presented papers at the San Antonio meeting were the following.

H. C. Cooke, "The Carbon-Ratio Theory, with Special Reference to North Texas"
J. F. Gallie, "The Relation of the Color of Soils to Climatic Zones"
J. W. Reiss, "Types of Geologic Structures Responsible for Major Petroleum Production in Texas"
Wayne Wood, "The Origin of Oil"

All finalists were seniors in geology at the University of Texas and received their degrees in June, 1941. The papers were very ably prepared and delivered, and made the selection of the winner a very difficult decision for the judges. J. F. Gallie was awarded first place.

J. F. GALLIE

J. F. GALLIE: born at Tampa, Florida, August 18, 1913. Graduate of Sam Houston High School, Houston, Texas. Attended University of Chicago, 1936-37; graduated with B. S. in geology, University of Texas, June, 1941.

Field trainee and accountant, Independent Exploration Company of Houston, 1935-36; chief computer, geochemical division of Subterrex in Houston, 1937; assistant business manager, 1938, and manager, 1939 to date, Society of Exploration Geophysicists. Member, Seismological Society of America; associate member, Society of Exploration Geophysicists.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 25, NO. 8 (AUGUST, 1941), PP. 1610-1612, 1 FIG.

Memorial

JESSE ELMORE SIMMONS
(1907–1941)

Jesse Elmore Simmons was born, April 27, 1907, in Kerens, Texas, and met his death on the morning of May 6, 1941, when his car struck a concrete bridge head near Ozona, Texas.

After graduation from High School in Kerens, he attended Austin College, the University of Texas, and the University of Colorado where he received the degree of Bachelor of Arts in geology in 1930. In the following year he continued his study of geology at the University of Oklahoma.

Soon after discovery of the East Texas oil field, he became an independent geologist and broker in that area where he demonstrated his ability as a geologist and business man.

He later served as a civilian engineering party chief for the United States Army on Mississippi River flood control in southern Louisiana.

At one time he was associated with the marketing department of Continental Oil Company, but resigned to engage in stock and bond brokerage in Denver, Colorado.

In 1935, he joined the geological staff of Continental Oil Company. He worked in the Rocky Mountain area until later that year when he moved to Midland, Texas, where he made his home.

He is survived by his wife, May Latham Simmons, a daughter, Peggy, his mother, and younger brother, Hal. He was a member of A.A.P.G., Alpha Tau Omega, and one time secretary of West Texas Geological Society.

Jesse won the respect and confidence of all who met him. His outstanding ability and unlimited capacity for friendship will be missed by all of us who knew him well.

E. W. KIMBALL

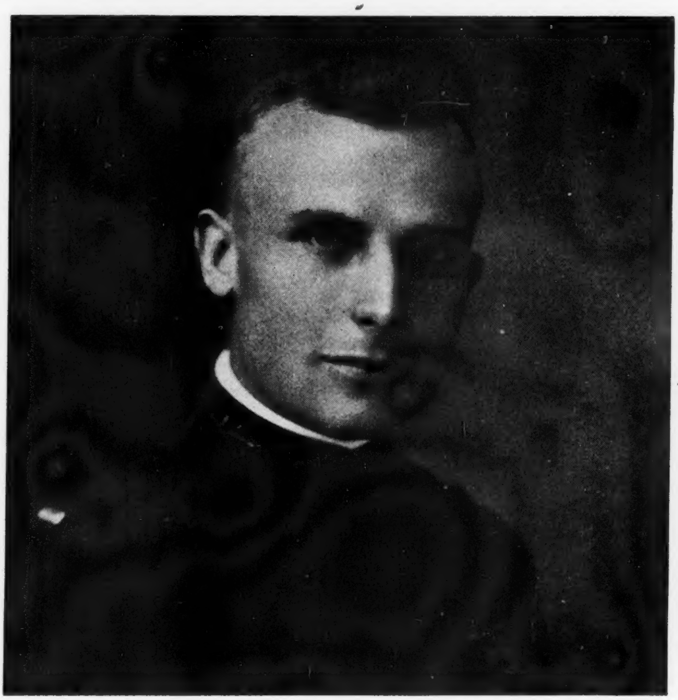
ROGER W. SAWYER
(1895–1941)

Roger W. Sawyer was born at Terral, Indian Territory (Oklahoma), April 21, 1895, the next youngest child of Dr. George W. Sawyer and Virginia Schoolfield Sawyer. His father was a pioneer physician of Indian Territory, and later moved to Oklahoma City, Oklahoma.

Roger Sawyer attended school at Marietta, Oklahoma; at Central High School, Oklahoma City, Oklahoma; and at the University Preparatory School, Norman, Oklahoma. He entered the University of Oklahoma in the fall of 1911 and received the Bachelor of Arts degree in the spring of 1915. He taught at Lexington, Oklahoma, in 1915–16 and at Eufaula, Oklahoma, in 1916–17.

Soon after the declaration of war with Germany, in 1917, he stood an examination for a commission as Second Lieutenant, Regular Army, at Fort Sill, Oklahoma, but there was some delay in learning the result, and, since he felt that his country needed him, he entered the Reserve Officers Training

School at Leon Springs, Texas. He was within three days of receiving a commission as First Lieutenant, Reserve Corps, when the commission as Second Lieutenant, Regular Army, arrived. On the advice of his Major he accepted the Regular Army commission though it gave him lower rank. He served through most of the war with the Thirteenth Cavalry on the Mexican border. Near the close of the war he was promoted to First Lieutenant, Regular Army, and stationed at Fort Benning, Georgia, where he attended the Artillery School. He resigned his commission at the close of the war.



Truby Studio, Norman

ROGER W. SAWYER

He did graduate work at the University of Oklahoma in 1919–20 and the following summer and fall did field work for the Choat Oil Corporation. From February through October, 1921, he was employed in topographic work with the United States Army Engineers on the Gulf Coast. From that time till his death he was engaged in geological work in Oklahoma, Texas, Arkansas, Tennessee, Kentucky, Illinois, the Black Hills of South Dakota, Nebraska, Colorado, and New Mexico. He had worked for the Skelly Oil Company and the Ramsey Petroleum Corporation, and at the time of his death was in the employ of the Pure Oil Company, working in New Mexico. But much of the

time he worked independently. He did further graduate work at the University of Oklahoma in 1932–33.

As an undergraduate, he was a member of Websterian Literary Society. He was elected to associate membership in the American Association of Petroleum Geologists in March, 1922, and to full membership in May, 1925, sponsored by W. C. Kite, J. B. Umpleby, and Clyde M. Becker. He was a member of Phi Beta Kappa, of Sigma Gamma Epsilon, and of Sigma Xi.

Roger Sawyer was conscientious in his work, careful, painstaking, and discreet. He had no desire to be in the "limelight," preferring that others occupy the center of the stage. His employers and associates knew him to be one of the best field geologists in the Southwest, and his opinion was valued by those who knew his thoroughness and integrity.

In connection with his routine work he contributed in no small degree to the common fund of geological knowledge. Perhaps his most outstanding contribution was a paper on the Permian stratigraphy in the Anadarko basin, Oklahoma, read at the Shreveport meeting of the Association, May, 1923, and published in Vol. 8, No. 3 of the *Bulletin*. At the time his views concerning that area were at variance with those generally held, but his conclusions are now generally accepted, in the main. His work was cut short in his prime.

He died at Roswell, New Mexico, March 16, 1941, in the midst of plans for further work in that vicinity. He slipped and fell from the roof of a garage. Death was instantaneous. He was buried at Rose Hill Cemetery, Chickasha, Oklahoma, March 19, 1941. He is survived by his father, Dr. George W. Sawyer, and a sister, Dr. Edith Hammond, both of Chickasha, Oklahoma; by a brother, W. C. Sawyer, of Lindsay, Oklahoma; and by two other sisters, Dr. Mary V. S. Sheppard, of Oklahoma City, Oklahoma, and Mrs. W. L. Vaughn, of Canyon, Texas.

Roger Sawyer had many friends, both within and without the profession who feel their loss keenly. He was always ready to offer assistance in our difficulties, to extend his sympathy on our reverses, and to rejoice with us in our success. To me he was among the truest and staunchest of friends and I feel the loss poignantly.

MALCOLM C. OAKES

NORMAN, OKLAHOMA
June, 1941

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 25, NO. 8 (AUGUST, 1941), PP. 1613-1616

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

ALBERT E. BRADBURY, of San Jose, California, is in the Flying Cadet Detachment at Lowry Field, Denver, Colorado.

RICHARD C. HARRIS, of the Atlantic Refining Company, has returned from Havana, Cuba, and may be addressed in care of the company, 260 South Broad Street, Philadelphia, Pennsylvania.

WAYNE E. WALCHER has completed work at the University of Illinois and is in the employ of the Gulf Oil Corporation at Wichita, Kansas.

ROBERT BARLING, of the Western Geophysical Company, has been transferred from Seminole, Texas, to Hanford, California.

ROBERT L. AUGENTHALER, recently with the California Company, is with the Standard Oil Company of British Columbia, Ltd., at Lethbridge, Alberta, Canada.

DAN H. MCLENDON, who has been with the Lane-Wells Company in Louisiana, is an officer in the 94th Coast Artillery (A.A.) at Camp Davis, North Carolina.

W. FARRIN HOOVER has moved from Mt. Vernon, Illinois, to 409 S.E. First Street, Evansville, Indiana.

G. LESLIE WHIPPLE has returned from service with the Indian Oil Concessions, Ltd., at Calcutta, and may be addressed at 1215 Atlantic Avenue, Long Beach, California.

A party from the department of geology and geography at Northwestern University will be engaged through the summer in the study of the pre-Cambrian rocks of the Los Pinos Range in central New Mexico. J. T. STARK and E. C. DAPPLES are in charge of the work, and will be assisted by HUGH GARRISON, JAMES NORTON, MORTIMER STAATZ, and RALPH WILPOLT. The project is financed by a grant from the University.

The South Louisiana Geological Society held its regular monthly meeting on June 17 in Lake Charles. G. E. CANNON, Humble Oil and Refining Company, Houston, Texas, gave a paper on "Mud Logging."

BAKER HOSKINS, 41, geologist with the Shell Oil Company, Inc., died on June 22 in Lake Charles from complications arising from an operation. Hoskins was treasurer of the South Louisiana Geological Society at the time of his death.

GROVER MURRAY, JR., has changed his address from the Louisiana Geological Survey to the Magnolia Petroleum Company, Jackson, Mississippi.

JACK F. DOUGHERTY is with the Federal Power Commission, with his office in the Neil P. Anderson Building, Fort Worth, Texas.

Donald F. Newell is on a year's leave of absence from the Phillips Petroleum Company. He is a lieutenant and battery commander of service battery, 61st Field Artillery, Fort Bliss, Texas.

Kenneth K. Landes, State geologist and assistant director of the Kansas Geological Survey, has resigned to become head of the department of geology at the University of Michigan.

Arthur J. Tieje, of Los Angeles, sailed for Buenos Aires on the ship *Del Brasil* of the Delta Line, New Orleans, on July 23. He will endeavor to secure some notoungulate and other bones from the museums at Buenos Aires and La Plata. His address in Buenos Aires is the Alvear Palace Hotel.

Captain Chas. Gill Morgan, of Dallas, Texas, is now stationed in Washington, D. C.. Captain Morgan can be addressed in care of the War Department, Office, Chief of the Air Corps, Washington, or Apt. 196, Arlington Village, Arlington, Virginia.

Riley G. Maxwell, associated with Merry Brothers and Perini during the past 10 years, has resigned to open an independent geological office at 418 Mims Building, Abilene, Texas.

William S. Hoffmeister has changed his address from the Lago Petroleum Corporation, Maracaibo, Venezuela, to the Carter Oil Company, Shreveport, Louisiana, where he is engaged in paleontological work.

James R. Hamilton is with the Mene Grande Oil Company, geological department, Apartado 234, Maracaibo, Venezuela.

T. E. Wall, formerly chief geologist with the Allied Oil Production Company is with the National Petroleum and Southwestern Royalty Companies of Tulsa, with offices at 704 Court Building, Evansville, Indiana.

Officers of the Alberta Society of Petroleum Geologists are: president, W. D. C. Mackenzie, Royalite Oil Company, Turner Valley, Alberta; vice-president, J. O. Galloway, Standard Oil Company of British Columbia, 700 Lancaster Building, Calgary; secretary-treasurer, W. C. Howells, McColl-Frontenac Oil Company, Ltd., 707 Lancaster Building, Calgary; business manager, D. B. Layer, Department of Natural Resources, Province of Alberta, Telephone Building, Calgary.

Officers of the Stratigraphic Society of Tulsa are: president, Ralph A. Brant, Atlantic Refining Company; vice-president, Kilburn E. Adams, The Texas Company; secretary-treasurer, Charles W. Lane, The Pure Oil Company.

Vincent C. Illing, professor at the Imperial College of Science and Technology, London, has been on a business trip in Trinidad, Venezuela, and the United States.

E. Russell Lloyd is vice-president of the Mimosa Corporation, operating in West Texas, with headquarters at Midland, Texas.

RICHARD HUGHES, formerly with the Burke-Greis Oil Corporation, is associated with C. C. CUMMINGS, PAUL J. MCINTYRE, and H. J. SHERMAN, oil producers, Tulsa, Oklahoma.

WALTER B. JONES, State geologist of Alabama, is in military service as an engineer reserve officer. STEWART J. LLOYD has taken over his duties at the office of the Geological Survey.

OSCAR CHAMPION, geologist for the Amerada Petroleum Corporation at Midland, Texas, has resigned to become district geologist for the Seaboard Oil Company at Midland.

H. HART PRATLEY, vice-president of the United Geophysical Company, Pasadena, California, died, July 23.

STANLEY S. SIEGFUS, with the Socony-Vacuum Oil Company, Inc., for 2 years in Venezuela, has returned to his home at Bakersfield, California.

The Pacific Section of the Association will hold its nineteenth annual fall meeting at Los Angeles, California, October 16 and 17, 1941.

The Petroleum Division of the A.I.M.E. will meet at Dallas, Texas, October 16, 17, and 18, and at Los Angeles, California, October 30 and 31.

The American Petroleum Institute will hold its twenty-second annual meeting at the St. Francis and the Palace hotels, San Francisco, California, October 30–November 3–7, 1941.

Lieutenant ROBERT J. GIVEN, A.C., Selfridge Field, Mount Clemens, Michigan, was formerly with the Dapar Oil Company, at Grand Rapids.

GEORGE B. SOMERS, recently with the Magnolia Petroleum Company, at Dallas, Texas, is working for the Naval Ordnance Laboratory. His address is 1010 F Street, NE., Washington, D. C.

WARREN W. MANKIN recently completed work for the degree of master of petroleum engineering at the University of Oklahoma, at Norman, and is working as natural gas engineer for the Oklahoma Natural Gas Company at Tulsa.

The Independent Petroleum Association of America will hold its twelfth annual meeting at Tulsa, Oklahoma, October 20–22, 1941.

T. E. SWIGERT, president of the Shell Oil Company, Inc., Houston, Texas, is secretary of the transportation committee of District 3, assisting in the Government co-ordination of petroleum.

E. L. DEGOLYER, geologist and consultant, Dallas, Texas, is staff director of conservation for the activities of the Office of Petroleum Co-ordinator for National Defense.

DEWITT T. RING, vice-president of the Columbia Oil and Gas Subsidiary Company, Columbus, Ohio, is a member of the production committee, District 1, of the Government-industry co-ordination of petroleum.

Eugene Law Ickes, of Los Angeles, died on July 7. Burial was at Deadwood, South Dakota.

Robert T. Hill, honorary member of the Association, for many years a geologist of the United States Geological Survey, and author of many geological works, died at Dallas, Texas, July 28, at the age of 82 years.

Robert L. Tucker, recently with the Arkansas Geological Survey, at Little Rock, has accepted a position with the General Geophysical Company at Houston, Texas.

Werner Tappolet, since 1938 with the Shell organization in The Netherlands and Venezuela, has returned to the United States. He may be addressed in care of Frederick Frei, 5762 Tuxedo Terrace, Los Angeles, California.

J. Elmer Thomas, petroleum analyst, Fort Worth, Texas, has been appointed as advisory consultant to the fuel section of the price division of the Office of Production Management.

Lee S. Osborne, exploitation engineer for the Shell Oil Company, Inc., Long Beach, California, is now executive assistant in the San Francisco office of the Company.

The International Petroleum Exposition will hold its twelfth oil show at Tulsa, Oklahoma, May 16–23, 1942. Gustav Egloff, Universal Oil Products, Chicago, Illinois, and B. B. Weatherby, Geophysical Research Corporation, Tulsa, Oklahoma, are co-chairmen of the technical and scientific committee, in charge of the Hall of Science.

Edwin S. Smith, Jr., consulting geologist and operator, died, July 28, at his home in Vernon, Texas, at the age of 31 years.

Willard F. Bailey is district geologist for the Skelly Oil Company at Midland, Texas.

David H. Graham is with Industrias Chimica Brasileiras "Dupirial," Rio de Janeiro, Brazil, S.A.

Samuel W. Riter, geologist with the Gulf Oil Corporation, Tulsa, Oklahoma, died while on a field trip near Rangely, Colorado, August 5.

John R. Gisburne, of the geological department of the Shell Oil Company, Inc., has moved from Tulsa, Oklahoma, to 1030 Stanley Drive, Wichita, Kansas.

John M. Golden, formerly with the Independent Exploration Company of Houston, is now with the Elflex Company, 1706 Niels Esperson Building, Houston, Texas.

KANSAS GEOLOGICAL SOCIETY

FIFTEENTH ANNUAL FIELD CONFERENCE, AUGUST 27–31

The Kansas Geological Society announces its fifteenth annual field conference to be held in central and eastern Missouri and western Illinois, August 27 to 31, inclusive. This conference is to be held in coöperation with the University of Missouri, the Missouri Geological Survey and Water Resources, and the State Geological Survey of Illinois.

The conference will study the pre-Pennsylvanian rocks of central and eastern Missouri and the Mississippian rocks in Illinois. Principal attention will be given to the Siluro-Devonian and the Ordovician rocks in Missouri. The conference leaders will be E. B. BRANSON, head of the department of geology at the University of Missouri; H. A. BUEHLER, State geologist of Missouri; and M. M. LEIGHTON, chief of the Geological Survey of Illinois. They will be assisted by H. S. MCQUEEN, assistant State geologist of Missouri, and J. MARVIN WELLER, head of the stratigraphy and paleontology division of the Illinois Geological Survey. The conference will convene at Sedalia, Missouri, and proceed as follows.

First day, Wednesday, August 27.—East and north from Sedalia by way of Boonville, Arrow Rock, Glasgow, and Fayette to Columbia, Missouri. Section extends from Jefferson City (Arbuckle) through Ordovician, Devonian, and Mississippian to lower Pennsylvanian rocks.

Second day, Thursday, August 28.—South from Columbia along Missouri River, crossing to Jefferson City and returning to Columbia at night. Examine in one outcrop along bluffs of Missouri River a section extending from Mississippian to Ordovician in which there are five unconformities.

Third day, Friday, August 29.—East of Columbia to view westernmost exposure of Plattin. Several new quarries have excellent exposures of Mississippian and Ordovician. Reach St. Louis in evening.

Fourth day, Saturday, August 30.—North from St. Louis, crossing Cap-au-Gres fault and associated folds. Section from Canadian up to Ste. Genevieve. Stratigraphy of Ordovician, Silurian, and Kinderhook-Mississippian. Stop at Hannibal, Missouri, in evening.

Fifth day, Sunday, August 31.—Cross Mississippi River. Excellent exposures of Kinderhook and other Mississippian formations. Trip ends at Nauvoo, Illinois.

Several papers on the stratigraphy and structure including maps and sections of the area will be included in the guide book.

Private automobiles will be used for transportation. If you are unable to bring your own car, the committee will undertake to provide you a seat in the car of another participant.

The registration fee will not exceed $9.00 and includes the price of one copy of the guide book. Additional copies may be purchased for not more than $5.00. All participants must pay the registration fee, no matter how much of the conference they attend.

It is important that the committee be able to make an estimate of the number of participants at the earliest possible date. If you hope to attend, or wish to receive further notices of the conference, write the Kansas Geological Society, 412 Union National Bank Building, Wichita, Kansas.

TWENTY-SEVENTH ANNUAL MEETING
DENVER, APRIL 21–24, 1942

The executive committee of the Association has accepted the invitation of the Rocky Mountain Association of Petroleum Geologists to hold the twenty-seventh annual meeting in Denver, Colorado, and has selected April 21–24, 1942, as the time. The Cosmopolitan is the convention headquarters hotel. Denver and the Cosmopolitan will awaken memories of earlier days in A.A.P.G. history, peculiarly pleasing to many members. The first regional meeting was held in Denver, October 26–28, 1922. It was in the Rocky Mountain metropolis that the unincorporated Association became a corporation under Colorado law, and Max W. Ball, Charles M. Rath, and Charles E. Decker set their hands and seals in testimony whereof on the twenty-first day of April, 1924. Somewhat more than 2 years later, in September, 1926, during the presidency of Alex W. McCoy, the Association held a mid-year meeting in Denver, at the Cosmopolitan, in conjunction with the western division of the American Mining Congress, the Colorado chapter of the American Institute of Mining and Metallurgical Engineers, and the American Silver Producers Association. One hundred petroleum geologists and 75 guests registered.

Denver is not far from the geographic center of the United States: a comfortable week-end train trip from either New York or Los Angeles; a day and a night from the Gulf Coast of Texas; and only a brief night's ride from the Great Lakes and central states. Denver has a population of 322,000. The altitude is 5,280 feet. From its thrilling origin in the days of the prospector's pick and sluice box, through its romantic history in the days of mining fortunes made and lost, to its present development of mines, mills, farms, railroads, educational opportunities, and natural environment, this convention city and oil capital of the Rocky Mountain states possesses a fascinating setting for a convention of petroleum geologists. In the Rocky Mountain region is the second oldest oil-producing district in the United States—the Cañon City-Florence district. At present the northern states to the Canadian border are the center of a new exploration development. The deposits of oil shales hold a large fuel reserve for the future.

The officers of the host society are: president, Miss Ninetta Davis, 224 U. S. Customs Building, Denver; first vice-president, James Boyd, Colorado School of Mines, Golden; second vice-president, H. E. Christensen, The Texas Company, Denver; secretary-treasurer, Dart Wantland, Colorado School of Mines, Golden.

Charles S. Lavington, of the Continental Oil Company, Denver, is the A.A.P.G. Rocky Mountain district representative and Carroll E. Dobbin, of the U. S. Geological Survey, Denver, is A.A.P.G. representative-at-large. A. E. Brainerd, of the Continental Oil Company, is A.A.P.G associate editor in the Rocky Mountain region.

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DIRECTORY OF GEOLOGICAL AND GEOPHYSICAL SOCIETIES

For Space Apply to A.A.P.G. Headquarters
Box 979, Tulsa, Oklahoma

COLORADO

ROCKY MOUNTAIN ASSOCIATION OF PETROLEUM GEOLOGISTS

DENVER, COLORADO

President - - - - - - - - - Ninetta Davis
224 U. S. Customs Building
1st Vice-President - - - - - - - - James Boyd
2nd Vice-President - - - - - H. E. Christensen
The Texas Company
Secretary-Treasurer - - - - - - Dart Wantland
927 Humboldt Street

Dinner meetings, first and third Mondays of each month, 6:15 P.M., Auditorium Hotel.

KANSAS

KANSAS GEOLOGICAL SOCIETY

WICHITA, KANSAS

President - - - - - - - - - John W. Inkster
Shell Oil Company, Inc.
Vice-President - - - - - - - - J. P. McKee
Consulting Geologist
Secretary-Treasurer - - - - - Lee H. Cornell
Stanolind Oil and Gas Company
Manager of Well Log Bureau - Harvel E. White

Regular Meetings: 7:30 P.M., Geological Room, University of Wichita, first Tuesday of each month. Visitors cordially welcomed.

The Society sponsors the Kansas Well Log Bureau which is located at 412 Union National Bank Building.

MICHIGAN

MICHIGAN GEOLOGICAL SOCIETY

President - - - - - - - - - Jed B. Maebius
Gulf Refining Company, Saginaw

Vice-President - - - - - - - - Lee C. Lamar
Carter Oil Company, Saginaw

Secretary-Treasurer - - - - - - Justin Zinn
Michigan State College, East Lansing

Business Manager - - - - - - Lee C. Miller
State Proration Officer, Lansing

Meetings: Monthly dinner meetings rotating between Saginaw, Mt. Pleasant, and Lansing. Informal dress.

ILLINOIS

ILLINOIS GEOLOGICAL SOCIETY

President - - - - - - - - - - - L. M. Clark
Shell Oil Company, Inc., Centralia

Vice-President - - - - - - - C. B. Anderson
Gulf Refining Company, Mattoon

Secretary-Treasurer - - - - - Robert G. Kurtz
The Ohio Oil Company, Marshall

Meetings will be announced.

LOUISIANA

THE SHREVEPORT GEOLOGICAL SOCIETY

SHREVEPORT, LOUISIANA

President - - - - - - - - Warren B. Weeks
Phillips Petroleum Co., 1009 Giddens-Lane Bldg.
Vice-President - - - - Weldon E. Cartwright
Tide Water Associated—Seaboard Oil Cos.
Secretary-Treasurer - - - - Van D. Robinson
Atlantic Refining Company, 1001 City Bank Bldg.
Historian - - - - - - - - - Robert B. Totten
Phillips Petroleum Company

Meets the first Friday of every month, 7:30 P.M., Civil Courts Room, Caddo Parish Court House. Special dinner meetings by announcement.

SOUTH LOUISIANA GEOLOGICAL SOCIETY

LAKE CHARLES, LOUISIANA

President - - - - - - - - - W. R. Canada
Stanolind Oil and Gas Company

Vice-President - - - - - - - - P. H. Jennings
Magnolia Petroleum Company

Secretary - - - - - - - - - E. M. Baysinger
Box 210

Meetings: Luncheon 1st Wednesday at Noon (12:00) and business meeting third Tuesday of each month at 7.00 P.M. at the Majestic Hotel. Visiting geologists are welcome.

TEXAS

FORT WORTH GEOLOGICAL SOCIETY
FORT WORTH, TEXAS

President - - - - - - - - - - Paul C. Dean
Consulting Geologist, W. T. Waggoner Building

Vice-President - - - - - - - - - C. L. Mohr
Ambassador Oil Corporation

Secretary-Treasurer - - - William J. Hilseweck
Gulf Oil Corporation, Box 1290

Meetings: Luncheon at noon, Worth Hotel, every Monday. Special meetings called by executive committee. Visiting geologists are welcome to all meetings.

HOUSTON GEOLOGICAL SOCIETY
HOUSTON, TEXAS

President - - - - - - - George S. Buchanan
Consulting Geologist, Esperson Building

Vice-President - - - - - - - - A. P. Allison
Sun Oil Company, Box 2659

Secretary - - - - - - - - - Leslie Bowling
Union Oil Company of California
1134 Commercial Building

Treasurer - - - - - - - - - Dugald Gordon
Brokaw, Dixon, and McKee, Gulf Building

Regular meeting held every Thursday at noon (12 o'clock) above Kelly's Restaurant, 910 Texas Avenue. For any particulars pertaining to the meetings write of call the secretary.

NORTH TEXAS GEOLOGICAL SOCIETY
WICHITA FALLS, TEXAS

President - - - - - - - - - - - J. R. Seitz
Seitz, Comegys, and Seitz, 531 Waggoner Building

Vice-President - - - - - - J. J. Russell, Jr.
Sinclair Prairie Oil Company
509 Hamilton Building

Secretary-Treasurer - - - - - - J. M. Clark
Tide Water Associated Oil Company
924 Hamilton Building

Luncheons and evening programs will be announced.

SOUTH TEXAS GEOLOGICAL SOCIETY
SAN ANTONIO AND CORPUS CHRISTI TEXAS

President - - - - - - - - - - Gentry Kidd
Stanolind Oil and Gas Company, San Antonio

Vice-President - - - - - - - - G. B. Gierhart
Humble Oil and Refining Company, Corpus Christi

Secretary-Treasurer - - - - W. W. Hammond
Magnolia Petroleum Company, 1709 Alamo National Building, San Antonio

Meetings: Third Friday of each month alternately in San Antonio and Corpus Christi. Luncheon every Monday noon at Milam Cafeteria, San Antonio, and at Plaza Hotel, Corpus Christi.

SOUTHWESTERN GEOLOGICAL SOCIETY
AUSTIN, TEXAS

President - - - - - - - - - - H. B. Stenzel
Bureau of Economic Geology

Vice-President - - - - William A. Bramlette
Univ. Texas, Dept. of Geology

Secretary-Treasurer - - - - - - Travis Parker
Univ. Texas, Dept. of Geology

Meetings: Every third Friday at 8:00 P.M. at the University of Texas, Geology Building 14.

WEST TEXAS GEOLOGICAL SOCIETY
MIDLAND, TEXAS

President - - - - - - - - - Robert E. King
Shell Oil Company, Inc.

Vice-President - - - - - - - - Fred F. Kotyza
Tide Water Associated Oil Company, Box 181

Secretary-Treasurer - - - - Walter G. Moxey
Stanolind Oil and Gas Company

Meetings will be announced

WEST VIRGINIA

THE APPALACHIAN GEOLOGICAL SOCIETY
CHARLESTON, WEST VIRGINIA
P.O. Box 1435

President - - - - - - - - - J. R. Lockett
Ohio Fuel Gas Co., Box 117, Columbus, Ohio

Vice-President - - - - - Charles Brewer, Jr.
Godfrey L. Cabot, Inc., Box 348, Charleston, W.Va.

Secretary-Treasurer - - - - - J. E. Billingsley
West Virginia Gas Corporation
Box 404, Charleston, W.Va.

Editor - - - - - - - - Robert C. Lafferty
Owens, Libbey-Owens Gas Department
Box 1375, Charleston, W.Va.

Meetings: Second Monday, each month, except June, July, and August, at 6:30 P.M., Kanawha Hotel.

THE SOCIETY OF EXPLORATION GEOPHYSICISTS

President - - - - - - - - - H. B. Peacock
Geophysical Service, Inc., Houston, Texas

Vice-President - - - - - - Frank Goldstone
Shell Oil Company, Inc., Houston, Texas

Editor - - - - - - - - - - R. D. Wyckoff
Gulf Research and Development Company
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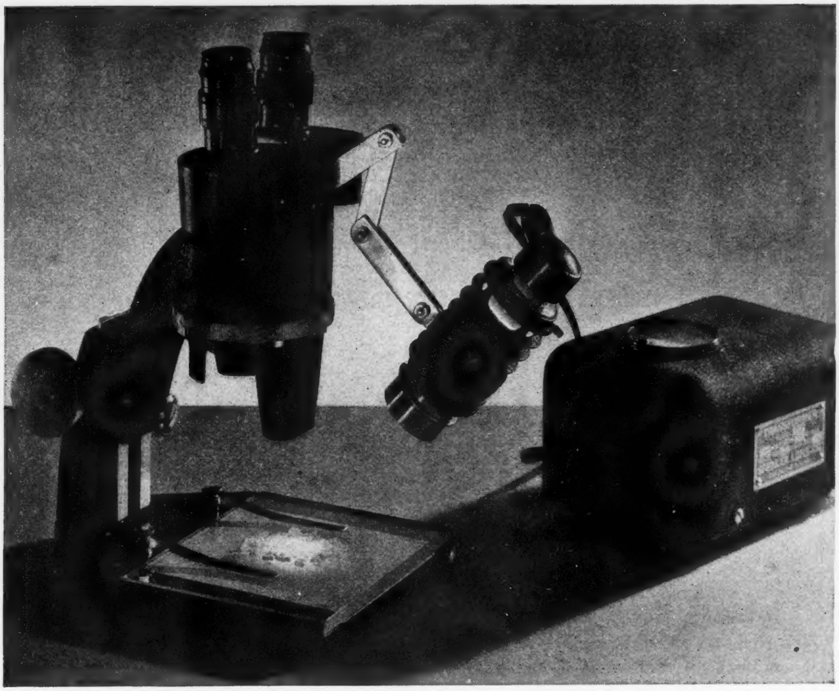
Secretary-Treasurer - - - William M. Rust, Jr.
Humble Oil and Refining Company
Box 2180, Houston, Texas

Past-President - - - - - - - - W. T. Born
Geophysical Research Corporation
Box 2040, Tulsa, Oklahoma

Business Manager - - - - - - - - J. F. Gallie
P.O. Box 777, Austin, Texas



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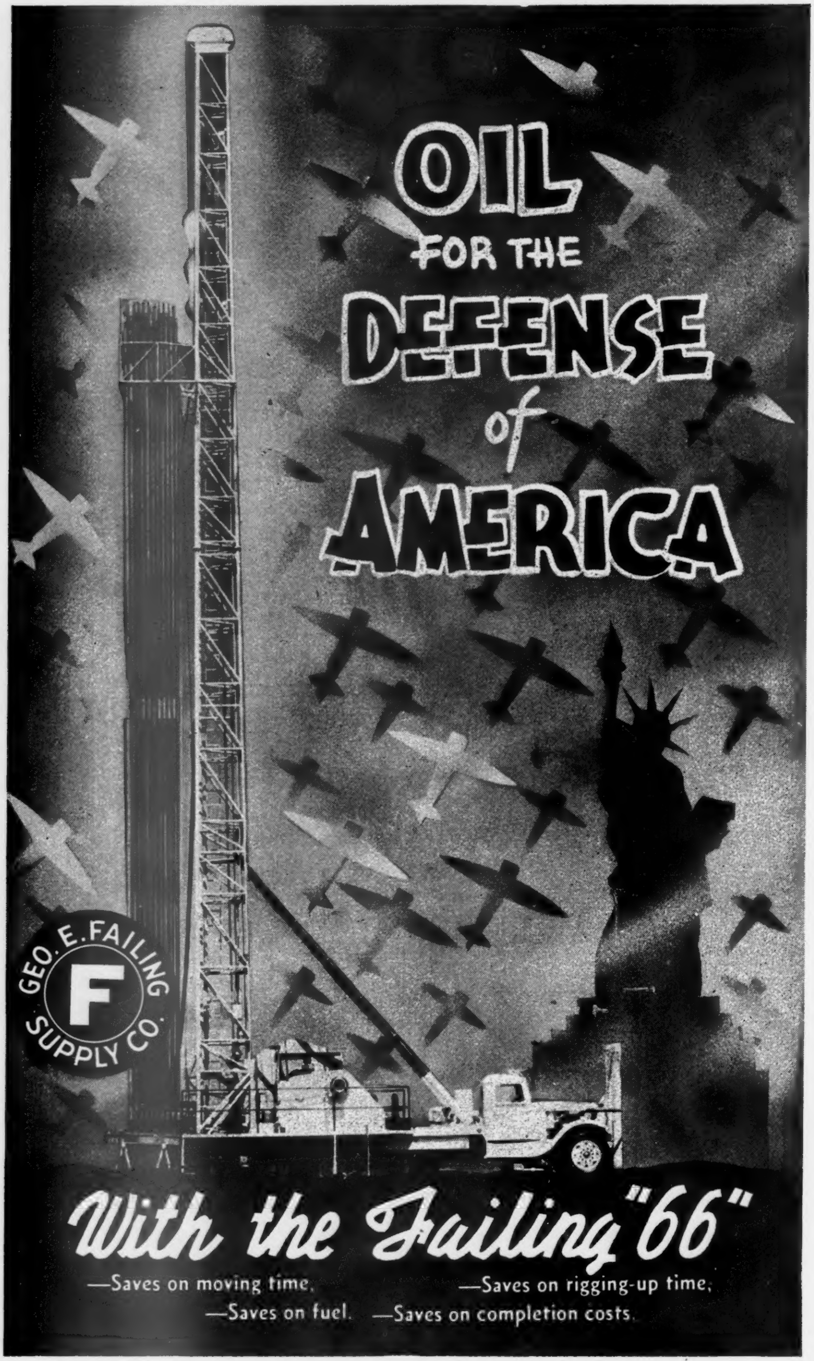
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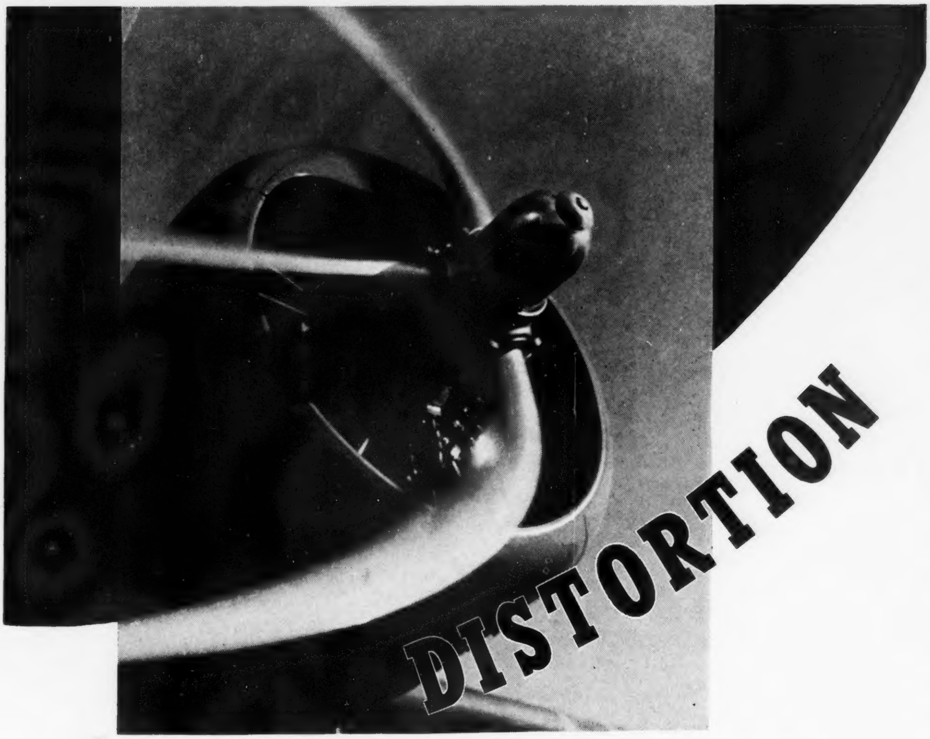
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